HIOKI

MR6000-01

MR6000-01
Dedicated Functions

MEMORY HiCORDER

EN

Feb. 2019 Revised edition 1
MR6000A968-01 19-02H

6005166611

Contents

Introduction

Thank you for choosing the Hioki MR6000-01 Memory HiCorder. Preserve this manual carefully and keep it handy to make full use of this instrument for a long time.

Model MR6000-01 Memory HiCorder is a model of Model MR6000 equipped with the following calculation functions (options).
- Digital filter calculation
- Real-time waveform calculation

Following manuals are provided along with these models. Refer to manuals relevant to your purpose.

Type	Contents	Printed	CD-stored File name
Operating Precautions	Information on the instrument for safe operations	✓	–
Quick Start Manual	Basic instructions and instrument specifications	✓	✓ MR6000A965-XX.pdf
Instruction Manual	Functions and instructions for the instrument	–	✓ MR6000A966-XX.pdf
MR6000-01 Dedicated Functions (This document)	Method to use functions including the calculation available only with Model MR6000-01	–	✓ MR6000A968-XX.pdf

Notation

*	Additional information is presented below.
☑	Indicates the initial setting values of the items. Initializing the instrument restores settings to each of these values.
(p.)	Indicates the location of reference information.
START (Bold-faced)	Names and keys on the screen are shown in boldface.
[ ]	Menus, dialogs, buttons in a dialog, and other names on the screen and the keys are indicated in brackets.
S/s	The number of times per second the analog input signals are digitized by the instrument is expressed in terms of “samples per second (S/s).” Example: “20 MS/s” (20 megasamples per second) indicates that the signal is digitized 20×10^6 times per second.

Descriptions of Functions

The following calculation functions are available with Model MR6000-01.
- Digital filter calculation function
- Real-time waveform calculation function

- Enabling the digital filter calculation eliminates specific frequency noises from the measured data.
- Real-time waveform calculations are possible for input signals and digital filter output.

How to Refer to This Guide

How to open the screen

Indicates the order of tapping the screens.

The button  represents the setting key.

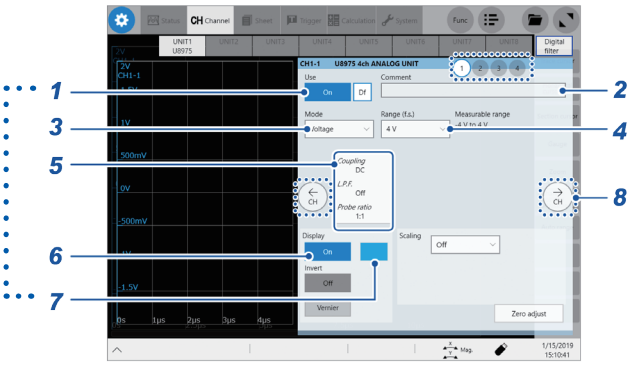
Sequence number

Numbered same as a corresponding step-by-step instruction.

Options and explanations

Describes selectable settings when an item is tapped.
The icon ☑ indicates the default setting of the item.

 > [Channel] > each module (UNIT)



1 Tap the [Use] button to set it to [On] or [Off].

On☑	Measures a waveform through this module.
Off	Does not measure any waveform through this module. Since no data is acquired, the instrument displays or saves nothing.

2 Enter a comment in the [Comment] box.

Number of characters that can be entered: up to 40

3 Tap the [Mode] box, and then choose a measurement mode from the list.

Voltage☑	Measures a waveform in voltage mode.
Temperature	Measures a waveform in temperature mode.

Selectable modes vary depending on the installed modules.
Refer to "3.6 Configuring Module-Specific Settings" of Instruction Manual.

4 Tap the [Range (f.s.)] box, and then choose a measurement range from the list.

The measurement ranges that can be chosen varies depending on modules.
If an input voltage exceeds the measurable range (overrange), change the measurement range to one with a lower sensitivity.

1 Digital Filter Calculation

Enabling the digital filter calculation eliminates specific frequency noises from the measured data. The digital filter calculation and the real-time waveform calculation cannot simultaneously be used.

- The digital filter can be configured to up to 32 channels of the modules installed in UNIT 1 to UNIT 8.
- The signals passing through the digital filter (digitally-filtered signal) are displayed on the waveform screen instead of input signals of configured channels.
- The digitally-filtered signals can be saved to and loaded from the storage media along with other input signals.
- The digitally-filtered signals can be used as the trigger sources.
- The numerical calculations can be performed for the digital-filtered signals.
  For details of digital filter characteristics, refer to “3.4 FIR Filter Characteristics” (p. 28) and “3.5 IIR (Butterworth) Filter Characteristics” (p. 41).

Functions available with [Digital filter]

The types of the digital filter calculations

- FIR filters (LPF, HPF, BPF, BSF)
- IIR filters (LPF, HPF, BPF, BSF)
- Moving average
- Delayer

Details about calculation formulas:
“3.1 Digital Filter” (p. 21)

1.1 Digital Filter Calculation Procedure

Since the instrument simultaneously performs calculation during measurement, you have to configure the digital filter calculation settings before a measurement.

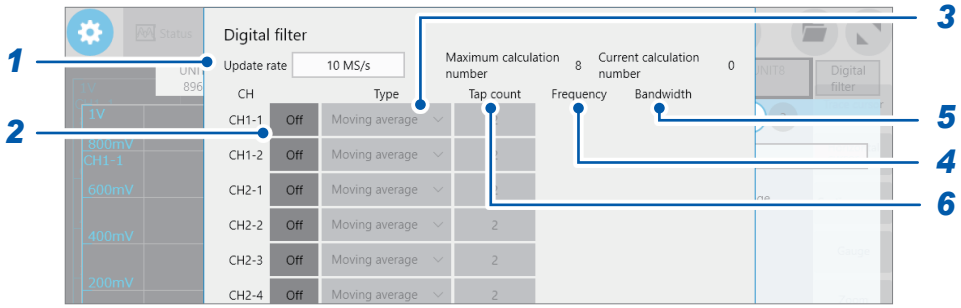
Setting the digital filter calculation	**Use > [Channel] > [Digital filter] for setting.(p.7)**
↓	
Starting a measurement	**The digital filter calculation starts simultaneously with the measurement.** (The response speed varies depending on the digital filter type and calculation update rate.) (p.27)
↓	
Acquiring data	**The instrument acquires the digitally filtered signals and other input signals when it is triggered.** (With no trigger setting, pressing the **START** key starts the instrument acquiring the digitally-filtered signals and other input signals.)
↓	
Displaying the waveforms	**The acquired data is displayed on the waveform screen.**
↓	
(Saving the data)	(When the auto-save is set to **[On]**.) **The acquired data is automatically saved to the storage media.**
↓	
Finishing the measurement	

1.2 Setting the Digital Filter Calculation

> [Channel] > [Digital filter]

The real-time waveform calculation function is turned off, which is accessible by proceeding in the following order:

> [Calculation] > [Real-time waveform calculation]



1 Tap the [Update rate] box, and then choose an update rate for the values calculated through digital filter.

This setting is different from the sampling rate.

10 MS/s☑, **1 MS/s**, **100 kS/s**, **10 kS/s**, **1 kS/s**, **100 S/s**, **10 S/s**, **1 S/s**

10 MS/s: The digital filter can be configured to a maximum of 8 channels.
1 MS/s: The digital filter can be configured to a maximum of 16 channels.
100 kS/s or lower: The digital filter can be configured to a maximum of 32 channels.

The calculation delay time varies depending on the calculation update rate.
Refer to “3.3 Calculation Delay Time” (p. 27).

2 Tap [Off] and set items to be used to [On].

- No channels of Model 8973 Logic Unit can be selected.
- No channels of Model MR8990 Digital Voltmeter Unit can be selected.

3 Tap the [Type] box, and then choose a filter from the list.

Moving average☑	Signals pass through the moving-average filter.
FIRLPF	Signals pass through the low-pass filter of FIR.
FIRHPF	Signals pass through the high-pass filter of FIR.
FIRBPF	Signals pass through the band-pass filter of FIR.
FIRBSF	Signals pass through the band-stop filter of FIR.

IIRLPF	Signals pass through the low-pass filter of IIR.
IIRHPF	Signals pass through the high-pass filter of IIR.
IIRBPF	Signals pass through the band-pass filter of IIR.
IIRBSF	Signals pass through the band-stop filter of IIR.
Delayer	Delays the waveform data.

Refer to “Filter type” (p. 21).

4 **In the [Frequency] box, specify the cut-off frequency and center frequency.**

(When you choose **[FIRLPF]**, **[FIRHPF]**, **[IIRLPF]**, or **[IIRHPF]** in the **[Type]** box)

FIRLPF, FIRHPF

Available cut-off frequency ranges vary depending on calculation update rates.

Calculation update rate	Cut-off frequency range
10 MS/s	400 kHz to 3 MHz*
1 MS/s	20 kHz to 300 kHz
100 kS/s	2 kHz to 30 kHz
10 kS/s	200 Hz to 3 kHz
1 kS/s	20 Hz to 300 Hz
100 S/s	2 Hz to 30 Hz
10 S/s	200 mHz to 3 Hz
1 S/s	20 mHz to 300 mHz

*: 900 kHz to 3 MHz for **FIRHPF**

IIRLPF, IIRHPF

Available cut-off frequency ranges vary depending on calculation update rates.

Calculation update rate	Cut-off frequency range
10 MS/s	20 kHz to 3 MHz
1 MS/s	2 kHz to 300 kHz
100 kS/s	200 Hz to 30 kHz
10 kS/s	20 Hz to 3 kHz
1 kS/s	2 Hz to 300 Hz
100 S/s	200 mHz to 30 Hz
10 S/s	20 mHz to 3 Hz
1 S/s	2 mHz to 300 mHz

(When you choose **[FIRBPF]**, **[FIRBSF]**, **[IIRBPF]**, or **[IIRBSF]** in the **[Type]** box)

FIRBPF, FIRBSF

Available center frequency ranges vary depending on calculation update rates.

Calculation update rate	Center frequency range
10 MS/s	800 kHz to 3 MHz*
1 MS/s	30 kHz to 300 kHz
100 kS/s	3 kHz to 30 kHz
10 kS/s	300 Hz to 3 kHz
1 kS/s	30 Hz to 300 Hz
100 S/s	3 Hz to 30 Hz
10 S/s	300 mHz to 3 Hz
1 S/s	30 mHz to 300 mHz

*: 1 MHz to 3 MHz for **FIRBPF**

IIRBPF, IIRBSF

Available center frequency ranges vary depending on calculation update rates.

Calculation update rate	Center frequency range
10 MS/s	1.3 MHz to 3 MHz
1 MS/s	130 kHz to 300 kHz
100 kS/s	13 kHz to 30 kHz
10 kS/s	1300 Hz to 3 kHz
1 kS/s	130 Hz to 300 Hz
100 S/s	13 Hz to 30 Hz
10 S/s	1300 mHz to 3 Hz
1 S/s	130 mHz to 300 mHz

5 **In the [Bandwidth] box, choose a frequency bandwidth (expressed by a percentage of the calculation update rate).**

(When you choose **[FIRBPF]**, **[FIRBSF]**, **[IIRBPF]**, or **[IIRBSF]** in the **[Type]** box)

The selectable frequency bandwidth varies depending on the filter type and calculation update rate.
Refer to “3.4 FIR Filter Characteristics” (p. 28) – “BPF characteristics” (p. 29),
“BSF characteristics” (p. 31)
“3.5 IIR (Butterworth) Filter Characteristics” (p. 41) –“BPF characteristics” (p. 45),
“BSF characteristics” (p. 47).

1%, **2%**, **5%**, **10%**, **15%**, **20%**

6 **In the [Tap count] box, choose a tap count.**

(When you choose **[Moving average]** or **[Delayer]** in the **[Type]** box)

[Moving average]

2☑, 4, 8, 16, 32, 64, 128*1

*1: When the calculation update rate is 10 MS/s, the following numbers can be set: 2, 4, 8, 16, 32

[Delayer]

0 to 200*2

*2: When the calculation update rate is 10 MS/s, the following numbers can be set: between 0 and 60

2 Real-time Waveform Calculation

- A maximum of 16 real-time waveform calculations can be configured.
- The digital filter calculation and the real-time waveform calculation cannot simultaneously be used.
- Any channel of the modules installed in UNIT 1 to UNIT 8 or results of the real-time waveform calculation can be selected as the calculation targets.
- Results of the real-time waveform calculation are displayed along with input signals on the waveform screen.
- Results of the real-time waveform calculation, as well as other input signals, can be stored to and loaded from storage media.
- Results of the real-time waveform calculation can be used as the trigger sources.
- The numerical calculations can be performed on results of the real-time waveform calculation.
- Although Model MR8990 Digital Voltmeter Unit has an A/D conversion resolution of 24 bits, the instrument uses only the upper 16 bits during the real-time waveform calculation.

Functions available with [Real-time waveform calculation]

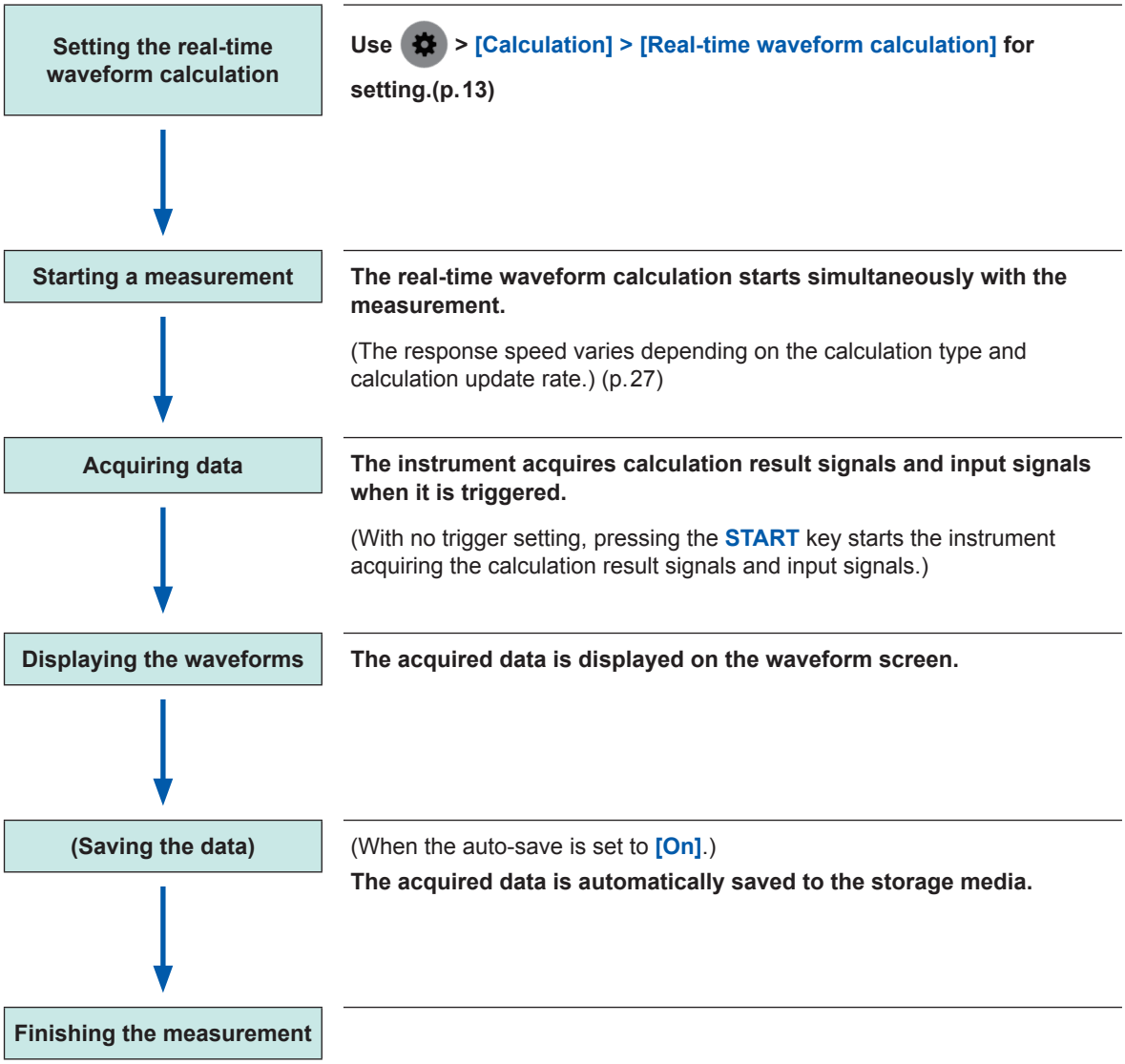
Real-time waveform calculation

- Arithmetic operations (+, −, ×, /)
- Arithmetic operations with coefficients (+, −, ×, /)
- Quartic polynomial
- Monomial
- Polynomial addition/subtraction
- Differentiation
- Integration (absolute, positive, negative, total)
- Accumulation (absolute, positive, negative, total)
- FIR filters (LPF, HPF, BPF, BSF)
- IIR filters (LPF, HPF, BPF, BSF)
- Moving average
- Delayer

Details about calculation formulas: “3.2 Real-time Waveform Calculation” (p. 24)

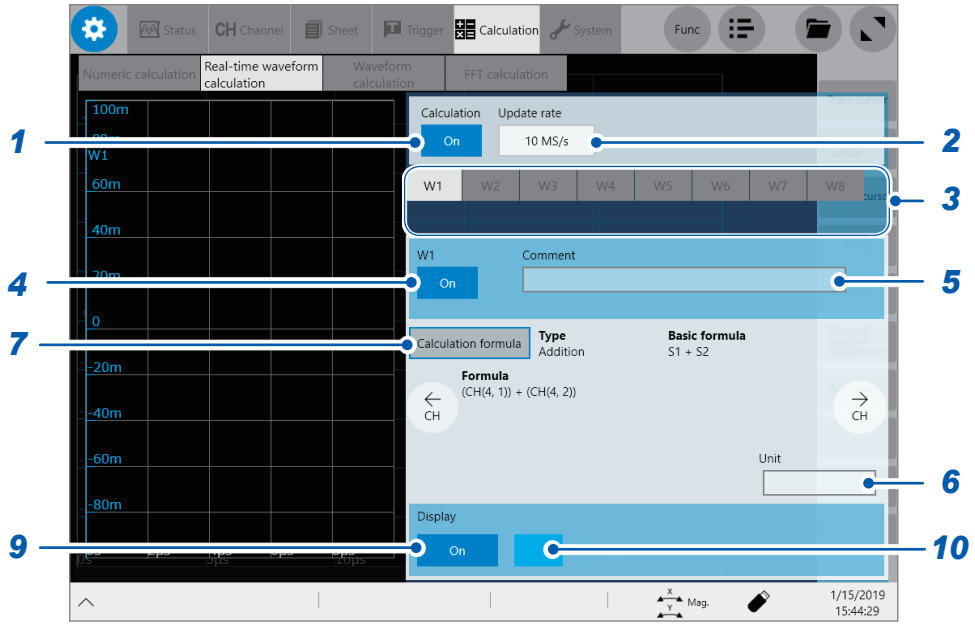
2.1 Real-time Waveform Calculation Procedure

Since the instrument simultaneously performs calculation during measurement, you have to configure the digital filter calculation settings before a measurement.



2.2 Setting the Real-time Waveform Calculation

> [Calculation] > [Real-time waveform calculation]



1 **Tap the [Calculation] button to set it to [On].**

(Default setting: [Off])

The digital filter calculation function is turned off, which is accessible by proceeding in the following order:

> [Channel] > [Digital filter]

2 **Tap the [Update rate] box, and then choose an update rate for the real-time waveform calculation values from the list.**

This setting is different from the sampling rate.

10 MS/s☑, 1 MS/s, 100 kS/s, 10 kS/s, 1 kS/s, 100 S/s, 10 S/s, 1 S/s

10 MS/s: Up to 8 real-time waveform calculations can be selected.
1 MS/s or less: Up to 16 real-time waveform calculations can be selected.

- The selectable calculation type varies depending on calculation update rate.
  Refer to “Fastest calculation update rate” (p. 26).
- The calculation delay time varies depending on the calculation update rate.
  Refer to “3.3 Calculation Delay Time” (p. 27).
- When the update rate is faster than the sampling rate, the calculation source data is decimated and the remaining data is recorded.
  To record entire calculation source data, set the calculation update rate equal to or less than the sampling rate.

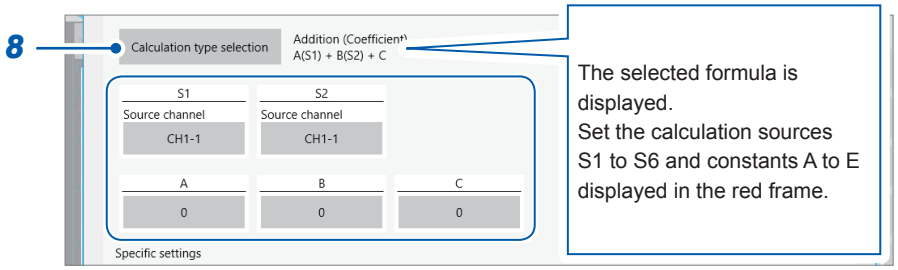
3 **Tap any one of the [W1] through [W16] buttons that you choose for a calculation.**

4 **Tap a channel number button you choose as a calculation channel to set it to [On].**

5 **Tap the [Comment] box, and then enter the comment.**

6 **Tap the [Unit] box, and then enter the unit.**

7 Tap [Calculation formula].



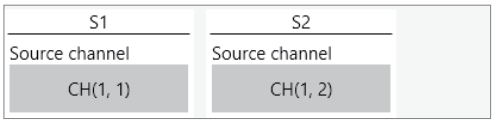
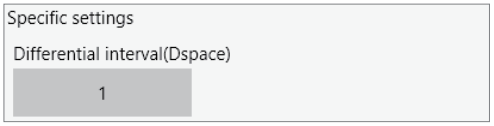
8 Tap [Calculation type selection], and then choose a calculation type, calculation target channels, and calculation conditions.

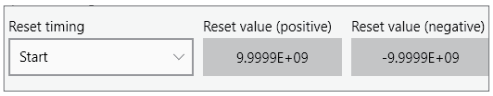
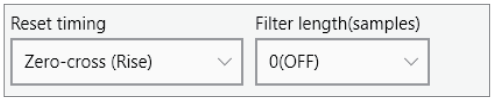
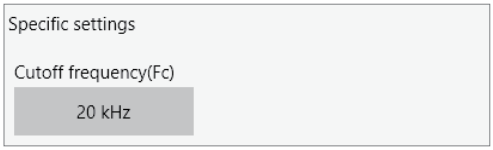
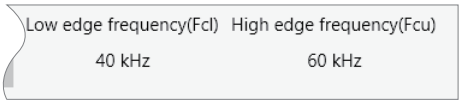
Calculation type	Formula	Description
Addition☑	S1 + S2	Addition of the waveform data
Subtraction	S1 − S2	Subtraction of the waveform data
Multiplication	S1 × S2	Multiplication of the waveform data
Division	S1 / S2	Division of the waveform data
Addition (Coefficient)	A × (S1) + B × (S2) + C	Addition with coefficient of the waveform data
Subtraction (Coefficient)	A × (S1) − B × (S2) + C	Subtraction with coefficient of the waveform data
Multiplication (Coefficient)	A × (S1) × B × (S2) + C	Multiplication with coefficient of the waveform data
Division (Coefficient)	A × (S1) / [B × (S2)] + C	Division with coefficient of the waveform data
Quartic polynomial	$A \times (S1)^4 + B \times (S1)^3 + C \times (S1)^2 + D \times (S1) + E$	Quartic polynomial of the waveform data
Monomial	A × (S1)	Monomial of the waveform data
Polynomial Calc.	A × (S1) + B × (S2) + C × (S3) + D × (S4)	Polynomial addition/subtraction of the waveform data
Differentiation	Diff (S1, Dspace)	Differentiation with fifth-order Lagrange interpolation formula
Integration (Absolute)	Integ1 (S1)	Amplitude: Integration with absolute trapezoid formula
Integration (Positive)	Integ2 (S1)	Amplitude: Integration with positive trapezoid formula
Integration (Negative)	Integ3 (S1)	Amplitude: Integration with negative trapezoid formula
Integration (Total)	Integ4 (S1)	Integration with amplitude trapezoid formula
Accumulation (Absolute)	Add1 (S1)	Amplitude: Absolute count
Accumulation (Positive)	Add2 (S1)	Amplitude: Positive count
Accumulation (Negative)	Add3 (S1)	Amplitude: Negative count
Accumulation (Total)	Add4 (S1)	Amplitude count
Moving average	MOVE (S1, P)	Passes through the moving-average filter.
FIR Low Pass Filter	FIRLPF (S1, Fc)	Passes through the low-pass filter of FIR.

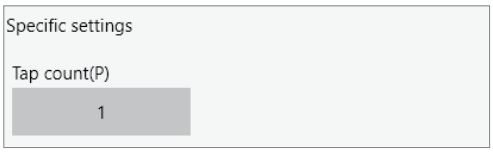
Calculation type	Formula	Description
FIR High Pass Filter	FIRHPF (S1, Fc)	Passes through the high-pass filter of FIR.
FIR Band Pass Filter	FIRBPF (S1, Fcl, Fcu)	Passes through the band-pass filter of FIR.
FIR Band Stop Filter	FIRBSF (S1, Fcl, Fcu)	Passes through the band-stop filter of FIR.
IIR Low Pass Filter	IIRLPF (S1, Fc)	Passes through the low-pass filter of IIR.
IIR High Pass Filter	IIRHPF (S1, Fc)	Passes through the high-pass filter of IIR.
IIR Band Pass Filter	IIRBPF (S1, Fcl, Fcu)	Passes through the band-pass filter of IIR.
IIR Band Stop Filter	IIRBSF (S1, Fcl, Fcu)	Passes through the band-stop filter of IIR.
Delayer	DELAY (S1, P)	Delays the waveform data.

Settings for calculation target channel and calculation conditions classified by calculation type

With an update rate of 10 MS/s, no real-time waveform calculation channels can be selected as a calculation target channel.

Calculation type	Settings	Description	Screen example
Addition **Subtraction** **Multiplication** **Division**	Calculation target channel (Analog, real-time waveform calculation)	Sets a calculation target channel.	
Addition (Coefficient) **Subtraction (Coefficient)** **Multiplication (Coefficient)** **Division (Coefficient)** **Monomial** **Quartic polynomial** **Polynomial** **Calc.**	Calculation target channel (Analog, real-time waveform calculation)	Sets a calculation target channel.	
	Coefficient*1 (A, B, C, D, E)	Sets the coefficient.	
Differentiation	Calculation target channel (Analog, real-time waveform calculation)	Sets a calculation target channel.	
	Differential interval (1 to 3,200)	Sets the sampling interval for derivation. Set one usually. However, to capture the changes of a waveform changing slowly, set a larger value.	

Calculation type	Settings	Description	Screen example
Integration (Absolute) **Integration (Positive)** **Integration (Negative)** **Integration (Total)** **Accumulation (Absolute)** **Accumulation (Positive)** **Accumulation (Negative)** **Accumulation (Total)**	Calculation target channel (Analog, real-time waveform calculation)	Sets a calculation target channel.	
	Reset timing (Start, over setting, rising of zero-cross, falling of zero-cross, zero-cross edge)	Sets the reset method for integration value or count.	
	Reset value (positive, negative)*1	When the reset timing is set to start or over setting, the specified values are set as the upper and lower limits.	
	Filter (Off to 10,000 samples)	Sets the width to find a zero crossing. Only when the calculation target channel signal has crossed the zero-level and has never crossed the zero-level again within the specified filter width, the waveform is considered to cross the zero-level. This is useful to exclude zero-level crossing events caused by noise.	
Moving average	Calculation target channel (Analog)	Sets a calculation target channel.	
	Tap count (2, 4, 8, 16, 32, 64, 128) *2	Sets the number of moving average points.	
FIR Filter (**LPF**, **HPF**, **BPF**, **BSF**) **IIR Filter** (**LPF**, **HPF**, **BPF**, **BSF**)	Calculation target channel (Analog)	Sets a calculation target channel.	
	Cut-off frequency or center frequency	Sets the frequency. Frequencies within the range shown in “Cut-off frequency or center frequency” (p. 18) are available.	
	Frequency bandwidth (1%, 2%, 5%, 10%, 15%, 20%)	• Sets a frequency bandwidth for **FIRBPF**, **FIRBSF**, **IIRBPF**, and **IIRBSF**. • Sets a frequency percentage of the calculation update rate. • Selectable frequency bandwidth varies depending on filter type and calculation update rate. *3	

Calculation type	Settings	Description	Screen example
Delayer	Calculation target channel (Analog)	Sets a calculation target channel.	
	Tap count (0 to 200)*4	Sets the number of delayed points.	

*1: Available setting range: −9.9999E+29 to −1.0000E−29, 0, +1.0000E−29 to +9.9999E+29
Number of significant figures is 5 digits.

*2: For a calculation update rate of 10 MS/s: 2, 4, 8, 16, 32
For a calculation update rate of 1 MS/s: 2, 4, 8, 16, 32, 64

*3: Refer to “3.4 FIR Filter Characteristics” (p. 28) – “BPF characteristics” (p. 29), “BSF characteristics” (p. 31) “3.5 IIR (Butterworth) Filter Characteristics” (p. 41) –“BPF characteristics” (p. 45), “BSF characteristics” (p. 47).

*4: For a calculation update rate of 10 MS/s: 0 to 50.

Cut-off frequency or center frequency

FIRLPF, FIRHPF	Calculation update rate	Cut-off frequency range
	10 MS/s	600 kHz to 3 MHz*1
	1 MS/s	20 kHz to 300 kHz*2
	100 kS/s	2 kHz to 30 kHz
	10 kS/s	200 Hz to 3 kHz
	1 kS/s	20 Hz to 300 Hz
	100 S/s	2 Hz to 30 Hz
	10 S/s	200 mHz to 3 Hz
	1 S/s	20 mHz to 300 mHz

*1: 1.2 MHz to 3 MHz for **FIRHPF**
*2: 40 kHz to 300 kHz for **FIRHPF**

IIRLPF, IIRHPF	Calculation update rate	Cut-off frequency range
	10 MS/s	20 kHz to 3 MHz
	1 MS/s	2 kHz to 300 kHz
	100 kS/s	200 Hz to 30 kHz
	10 kS/s	20 Hz to 3 kHz
	1 kS/s	2 Hz to 300 Hz
	100 S/s	200 mHz to 30 Hz
	10 S/s	20 mHz to 3 Hz
	1 S/s	2 mHz to 300 mHz

FIRBPF, FIRBSF	Calculation update rate	Center frequency range
	10 MS/s	800 kHz to 3 MHz*1
	1 MS/s	30 kHz to 300 kHz*2
	100 kS/s	3 kHz to 30 kHz
	10 kS/s	300 Hz to 3 kHz
	1 kS/s	30 Hz to 300 Hz
	100 S/s	3 Hz to 30 Hz
	10 S/s	300 mHz to 3 Hz
	1 S/s	30 mHz to 300 mHz

*1: 1.2 MHz to 3 MHz for **FIRBPF**
*2: 50 kHz to 300 kHz for **FIRBPF**

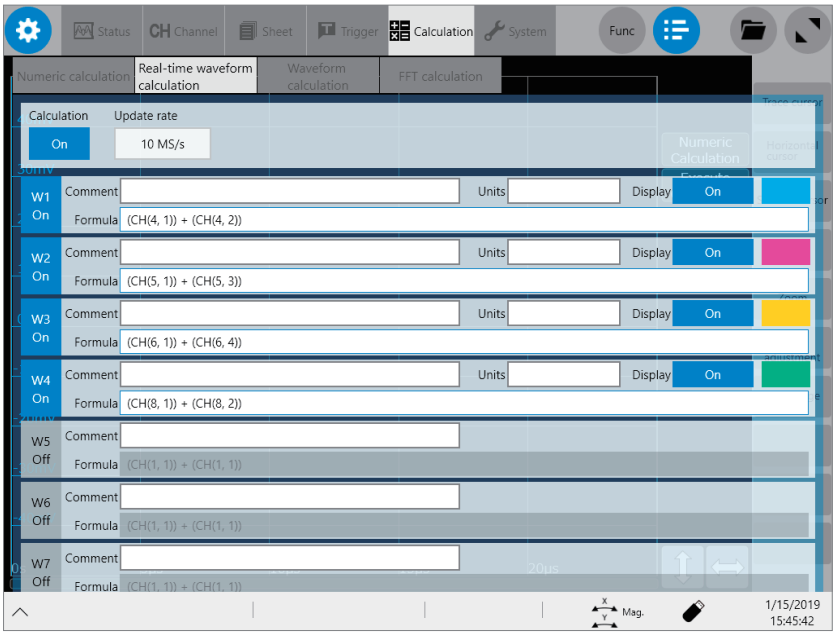
IIRBPF, IIRBSF	Calculation update rate	Center frequency range
	10 MS/s	1.3 MHz to 3 MHz
	1 MS/s	130 kHz to 300 kHz
	100 kS/s	13 kHz to 30 kHz
	10 kS/s	1300 Hz to 3 kHz
	1 kS/s	130 Hz to 300 Hz
	100 S/s	13 Hz to 30 Hz
	10 S/s	1300 mHz to 3 Hz
	1 S/s	130 mHz to 300 mHz

9 **Tap the [Display] button to set it to [On].**

10 **Tap the color box and choose the waveform color from the color palette.**
You can select the same color as other channels.

Checking the settings on the listing screen

> [Calculation] > [Real-time waveform calculation] >



3 Appendix

3.1 Digital Filter

Filter type

Filter name	Description
FIRLPF (Finite impulse response low-pass filter) **IIRLPF** (Infinite impulse response low-pass filter)	Passes low-frequency components and eliminates high-frequency noise.
FIRHPF (Finite impulse response high-pass filter) **IIRHPF** (Infinite impulse response high-pass filter)	Passes high-frequency components and eliminates low-frequency noise.
FIRBPF (Finite impulse response band-pass filter) **IIRBPF** (Infinite impulse response band-pass filter)	Passes only the components within the specified frequency band and eliminates low- and high-frequency noise.
FIRBSF (Finite impulse response band-stop filter) **IIRBSF** (Infinite impulse response band-stop filter)	Passes low- and high-frequency components and eliminates noise of specified frequency band.
Moving average (LPF)	Passes low-frequency components and eliminates high-frequency noise.
Delayer	Delays input signals by the number of taps.

FIR digital filters (LPF, HPF, BPF, BSF)

FIR stands for finite impulse response.

Advantages: These filters have linear-phase characteristics (Phase difference is proportional to frequency.), reducing phase distortion (phase delay). Since the input signals that have not been involved in any calculations are used for the filter calculation, the calculated output signals do not diverge, resulting in stable output signals.

Disadvantages: Higher orders are required to obtain steep cut-off characteristics. However, higher orders require longer calculation time.

IIR digital filters (LPF, HPF, BPF, BSF)

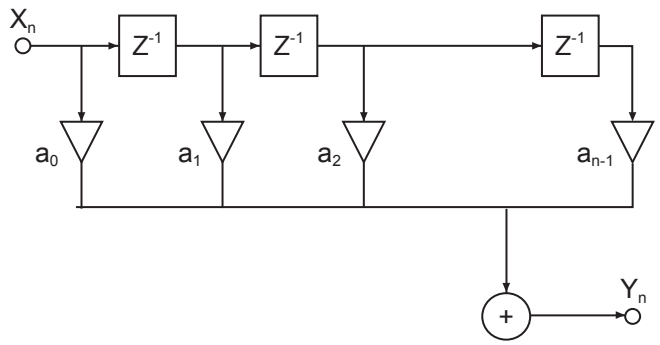
IIR stands for infinite impulse response.
The IIR digital filters of the instrument use Butterworth type, which has flat pass-band characteristics.

Advantages: Lower orders are sufficient to obtain sharp cut-off characteristics. Lower orders require shorter calculation time.

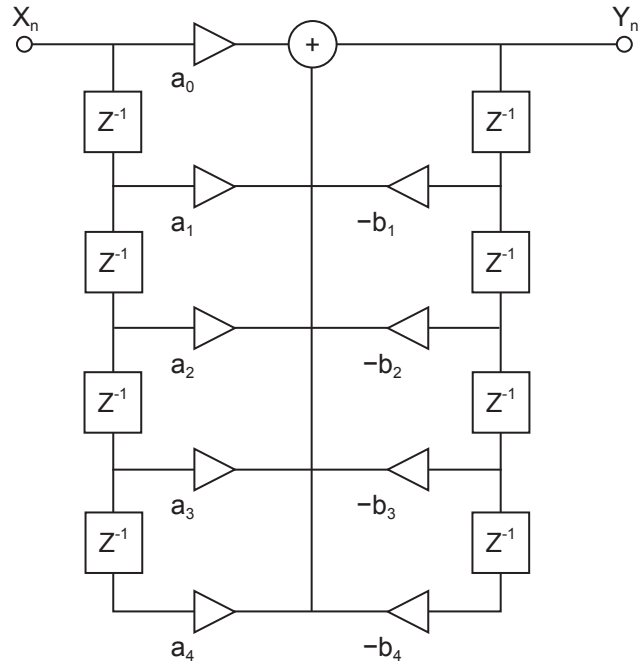
Disadvantages: These filters have non-linear phase characteristics (Phase difference is not proportional to frequency.), causing higher phase distortion (phase delay). Since the input signals that have not been involved in any calculations and the output signals that have been involved in any calculations are used for the filter calculation, the calculated output signals diverge, resulting in unstable output signals.

Filter configuration

FIR digital filter configuration (n-th-order FIR digital filter)

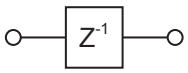


IIR digital filter configuration (fourth-order IIR digital filter)



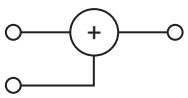
Delayer

The component that delays input signals by one sampling time



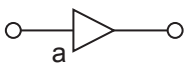
Adder

The component that outputs the sum of two input signals



Multiplier

The component that outputs multiplication of input signal by constant a



Group delay characteristics

The term, group delay means a time lag (s), which occurs due to the filter response characteristics, between an input frequency (sine wave) and an output frequency.
The group delay can be normalized by a calculation update interval (Ts), expressed in terms of "s/Ts."
The group delay for each frequency can be calculated by the following equation:
(Group delay of each frequency) × (Calculation update interval)

Example:
A group delay for a moving average is expressed by the following equation (constant independent of frequency):

Group delay for moving average [s/Ts] = (Number of times the moving average is tapped − 1) / 2

Let the number of times the moving average is tapped be 16.
Group delay [s/Ts] = (16 − 1) / 2 = 15 / 2 = 7.5 s/Ts

Let the calculation update rate (fs) be 100 kS/s.
Ts = 1 / fs = 1 / (100 kS/s) = 10 µs

Thus,

Delay time = Group delay × Calculation update interval = 7.5 s/Ts × 10 µs = 75 µs

3.2 Real-time Waveform Calculation

Calculation type

W[i]: i-th data of real-time waveform calculation, d[i]: i-th data of source channel

Calculation type	Description
Addition, Subtraction, Multiplication, Division **S1 + S2** **S1 − S2** **S1 × S2** **S1 / S2**	Performs addition, subtraction, multiplication, or division for the waveform data assigned to sources S1 and S2.
Addition/Subtraction/Multiplication/ Division (Coefficient) **A(S1) + B(S2) + C** **A(S1) − B(S2) + C** **A(S1) × B(S2) + C** **A(S1) / B(S2) + C**	Performs addition, subtraction, multiplication, or division with a coefficient for the waveform data assigned to sources S1 and S2.
Monomial **A(S1)**	Makes a calculation using a monomial of the waveform data assigned to source S1.
Quartic polynomial $A(S1)^4 + B(S1)^3 + C(S1)^2 + D(S1) + E$	Makes a calculation using a quartic polynomial of the waveform data assigned to source S1.
Polynomial Calc. **A(S1) + B(S2) + C(S3) + D(S4)**	Performs addition or subtraction for the waveform data assigned to sources S1, S2, S3, and S4.
Differentiation **Diff(S1)**	Differentiates the waveform data assigned to source S1 using the fifth-order Lagrange interpolation formula (intermediate difference). A group delay (2 × calculation update interval × ds) occurs. W[0] = 0 ↓ W[2 × ds − 1] = 0 W[2 × ds] = 1/(12Δt){8d[1 × ds] − d[2 × ds]} ↓ W[3 × ds − 1] = 1/(12Δt){8d[2 × ds − 1] − d[3 × ds − 1]} W[3 × ds] = 1/(12Δt){−8d[0] + 8d[2 × ds] − d[3 × ds]} ↓ W[4 × ds − 1] = 1/(12Δt){−8d[1 × ds − 1] + 8d[3 × ds − 1] − d[4 × ds − 1]} W[n × ds] = 1/(12Δt){d[(n − 4) × ds] − 8d[(n − 3) × ds] + 8d[(n − 1) × ds] − d[n × ds]} Ds: Differential spacing Δt = Calculation update interval × Differential interval
Integration (Absolute, Positive, Negative, Total) **Integ(S1)**	Integrates an instant value of the waveform data assigned to source S1 on an integration condition using the trapezoid formula based. W[0] = 0 ; W[1] = (d[0] + d[1])Δt / 2 W[2] = (d[0] + d[1])Δt / 2 + (d[1] + d[2])Δt/2 = W[1] + (d[1] + d[2])Δt/2 ↓ W[n] = W[n − 1] + (d[n − 1] + d[n])Δt / 2 d[i]: Substitute zero when the integration condition is not satisfied. Δt = Calculation update interval

Calculation type	Description
Accumulation (Absolute, Positive, Negative, Total) **Add(S1)**	Accumulates instant values of the waveform data assigned to source S1 based on an accumulation condition. W[0]= d [0] ; W[1]=(d [0] +d [1])= W [0] +d [1] ↓ W[n]=W [n−1] + (d[n −1] +d [n]) d[i]: Substitute zero when the accumulation condition is not satisfied.
Moving average **MOVE(S1)**	Applies the moving average filter the number of the specified taps repeatedly.
FIR Filter (LPF, HPF, BPF, BSF) **FIR(S1)**	Applies the FIR filter with a pass-band ripple of 0.8 dB and a cut-off attenuation of −40 dB.
IIR Filter (LPF, HPF, BPF, BSF) **IIR(S1)**	Applies the Butterworth IIR filter.
Delayer **DELAY(S1)**	Delays input signals in the timebase direction by the specified number of taps.

Fastest calculation update rate

The fastest calculation update rate for each calculation type is as follows.

Calculation type	Formula	Fastest calculation update rate
Addition	S1 + S2	10 MS/s
Subtraction	S1 − S2	10 MS/s
Multiplication	S1 × S2	10 MS/s
Division	S1 / S2	10 MS/s
Addition (Coefficient)	A × (S1) + B × (S2) + C	10 MS/s
Subtraction (Coefficient)	A × (S1) − B × (S2) + C	10 MS/s
Multiplication (Coefficient)	A × (S1) × B × (S2) + C	10 MS/s
Division (Coefficient)	A × (S1) / [B × (S2)] + C	10 MS/s
Quartic polynomial	$A \times (S1)^4 + B \times (S1)^3 + C \times (S1)^2 + D \times (S1) + E$	10 MS/s
Monomial	A × (S1)	10 MS/s
Polynomial addition/ subtraction	A × (S1) + B × (S2) + C × (S3) + D × (S4)	10 MS/s
Differentiation	Diff (S1, Dspace)	10 MS/s
Integration (Absolute)	Integ1 (S1)	1 MS/s
Integration (Positive)	Integ2 (S1)	1 MS/s
Integration (Negative)	Integ3 (S1)	1 MS/s
Integration (Total)	Integ4 (S1)	1 MS/s
Accumulation (Absolute)	Add1 (S1)	1 MS/s
Accumulation (Positive)	Add2 (S1)	1 MS/s
Accumulation (Negative)	Add3 (S1)	1 MS/s
Accumulation (Total)	Add4 (S1)	1 MS/s
FIR Filter	FIR (S1, Fc)	10 MS/s
IIR Filter	IIR (S1, Fc)	10 MS/s
Moving average	MOVE (S1, P)	10 MS/s
Delayer	DELAY (S1, P)	10 MS/s

3.3 Calculation Delay Time

The calculation delay times for the calculation update rates are as follows.

Phases of calculated waveforms lag behind the input signals by the calculation delay time.
For the moving average, FIR filter, IIR filter calculations, phases of calculated waveforms lag behind the input signals by the sum of the calculation delay time and group delay time.
For the delayer calculation, phases of calculated waveforms lag behind the input signals by the sum of the calculation delay time and tap count.

Calculation update rate	Calculation delay time
10 MS/s	6.2 µs or 6.3 µs
1 MS/s	5 µs
100 kS/s	20 µs
10 kS/s or less	Calculation update interval

Following periods are added when a real-time waveform calculation channel is selected as a calculation source.

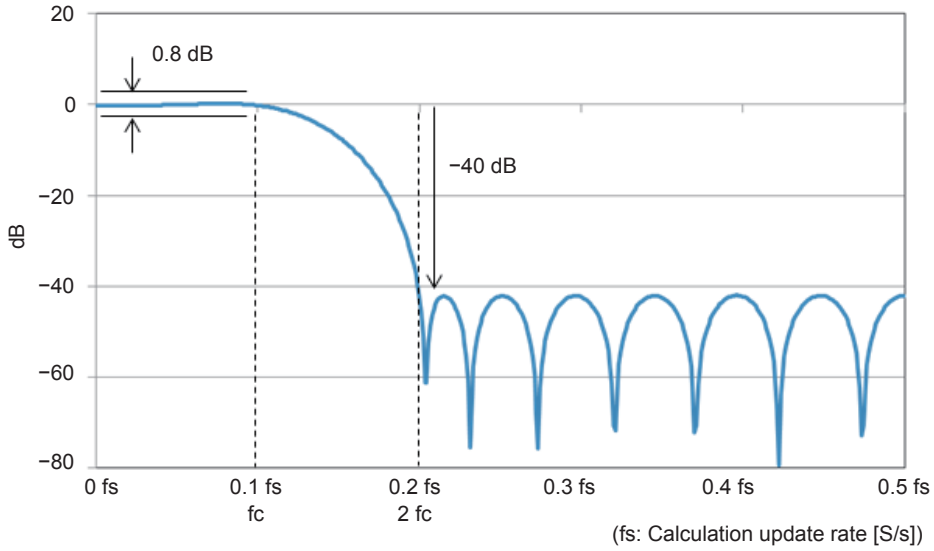
Calculation update rate	Calculation delay time to be added
10 MS/s	1.6 µs
1 MS/s	2 µs
100 kS/s	10 µs
10 kS/s or less	Calculation update interval

3.4 FIR Filter Characteristics

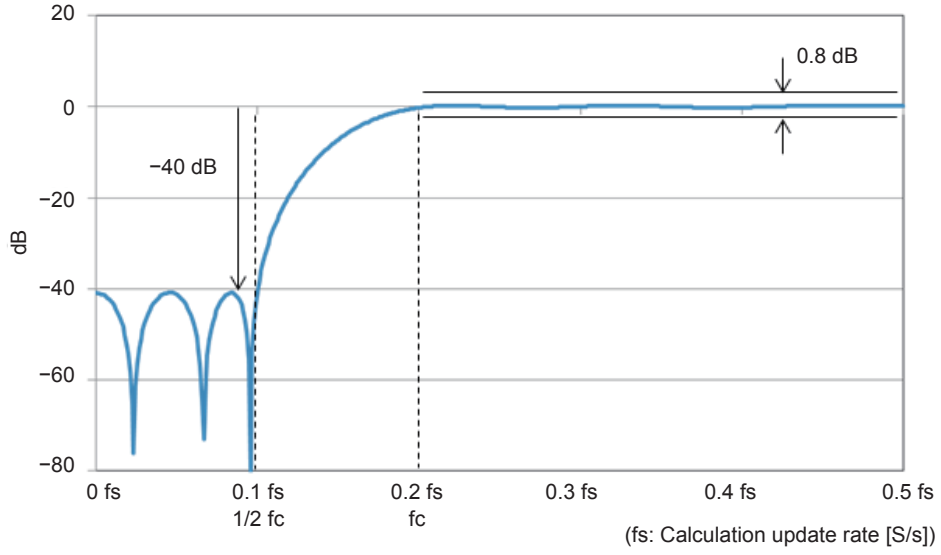
LPF and HPF characteristics

- The pass-band ripple falls within 0.8 dB.
- The LPF attenuation stands at approximately −40 dB at double the frequency of the cut-off frequency fc.
- The HPF attenuation stands at approximately −40 dB at half the frequency of the cut-off frequency fc.
- The stop-band attenuation stands at approximately −40 dB.

Example of FIR–LPF frequency characteristics



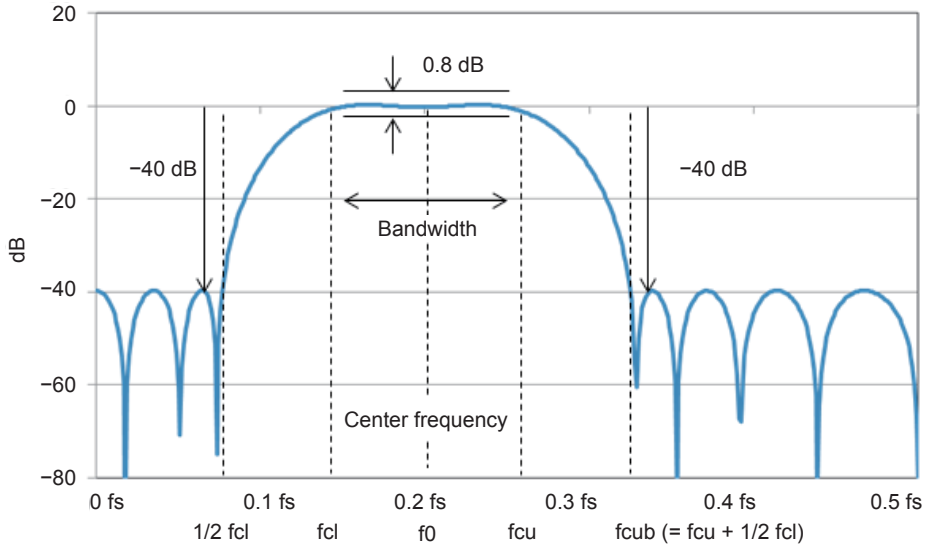
Example of FIR–HPF frequency characteristics



BPF characteristics

- The pass-band ripple falls within 0.8 dB.
- The attenuation stands at approximately −40 dB at half the lower pass-band edge frequency fcl.
- The attenuation stands at approximately −40 dB at the frequency higher than the higher pass-band edge frequency fcu by the same width as the lower-side transition width.
- The stop-band attenuation stands at approximately −40 dB.

Example of FIR–BPF frequency characteristics



Where the center frequency of the band-pass filter is f0 and the bandwidth is fw, the lower pass-band edge (fcl) and the upper pass-band edge (fcu) are calculated by the following expressions:

fcl = f0 − fw/2

fcu = f0 + fw/2

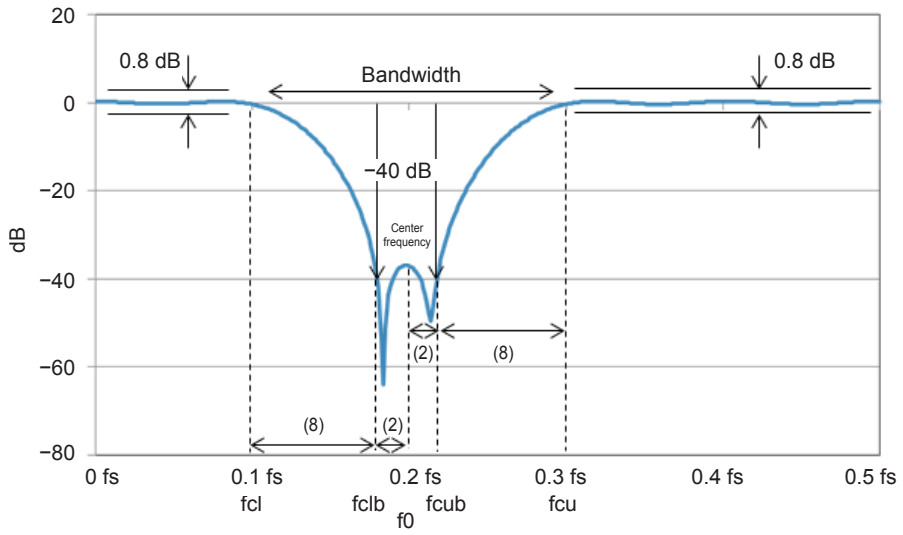
The bandwidth that can be set for the FIR band-pass filter varies depending on the center frequency.

Center frequency [Hz]	Frequency bandwidth [Hz]	Calculation update rate [S/s]
1.9 M to 3 M	200 k, 500 k, 1 M, 1.5 M, 2 M	10 M
1.6 M to 1.8 M	200 k, 500 k, 1 M, 1.5 M	10 M
1.4 M, 1.5 M	200 k, 500 k, 1 M	10 M
1.1 M to 1.3 M	200 k, 500 k	10 M
1 M	200 k	10 M
120 k to 300 k	20 k, 50 k, 100 k, 150 k, 200 k	1 M
100 k, 110 k	20 k, 50 k, 100 k, 150 k	1 M
70 k to 90 k	20 k, 50 k, 100 k	1 M
50 k, 60 k	20 k, 50 k	1 M
30 k, 40 k	20 k	1 M
12 k to 30 k	2 k, 5 k, 10 k, 15 k, 20 k	100 k
10 k, 11 k	2 k, 5 k, 10 k, 15 k	100 k
7 k to 9 k	2 k, 5 k, 10 k	100 k
5 k, 6 k	2 k, 5 k	100 k
3 k, 4 k	2 k	100 k

BSF characteristics

- The pass-band ripple falls within 0.8 dB.
- The attenuation stands at approximately −40 dB at the frequency fclb, which is higher than the lower pass-band edge by 80% of the frequency difference between the lower pass-band edge and center frequency.
- The attenuation stands at approximately −40 dB at the frequency fcub, which is lower than the higher pass-band edge by 80% of the frequency difference between the higher pass-band edge and center frequency.
- The stop-band attenuation stands at approximately −40 dB.

Example of FIR–BSF frequency characteristics



The bandwidth that can be set for the FIR band stop filter varies depending on the center frequency.

Center frequency [Hz]	Frequency bandwidth [Hz]	Calculation update rate [S/s]
1 M to 3 M	1.5 M, 2 M	10 M
800 k, 900 k	1.5 M	10 M
100 k to 300 k	50 k, 100 k, 150 k, 200 k	1 M
80 k, 90 k	50 k, 100 k, 150 k	1 M
50 k to 70 k	50 k, 100 k	1 M
30 k, 40 k	50 k	1 M
10 k to 30 k	5 k, 10 k, 15 k, 20 k	100 k
8 k, 9 k	5 k, 10 k, 15 k	100 k
5 k to 7 k	5 k, 10 k	100 k
3 k, 4 k	5 k	100 k

Filter order

The orders of FIR filter are as follows.
The cut-off frequencies and center frequencies are expressed as ratios of the calculation update rate in terms with percent.

FIR–LPF order

Cut-off frequency	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%
Order	96	64	46	38	32	27	24	21	18	17	15	14
Cut-off frequency	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%
Order	13	12	11	10	9	8	8	7	7	6	6	5
Cut-off frequency	26%	27%	28%	29%	30%							
Order	5	5	5	5	5							

FIR–HPF order

Cut-off frequency	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%
Order	194	134	100	80	68	54	48	42	40	36	34	32
Cut-off frequency	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%
Order	28	26	26	24	22	22	20	18	18	18	16	16
Cut-off frequency	26%	27%	28%	29%	30%							
Order	14	14	14	14	12							

FIR–BPF order, bandwidth: 2%

Center frequency	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%
Order	192	128	96	77	64	55	48	43	38	35	32	29
Center frequency	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%
Order	27	25	24	22	21	20	18	18	17	16	15	14
Center frequency	27%	28%	29%	30%								
Order	14	13	13	12								

FIR–BPF order, bandwidth: 5%

Center frequency	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%
Order	153	110	85	70	59	51	43	40	36	33	30	28
Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	26	24	23	21	20	19	18	17	16	15	15	14
Center frequency	29%	30%										
Order	13	13										

FIR–BPF order, bandwidth: 10%

Center frequency	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%
Order	192	128	96	77	64	55	48	43	38	35	32	29
Center frequency	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%
Order	27	25	24	22	21	20	18	17	17	16	15	14

FIR–BPF order, bandwidth: 15%

Center frequency	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%
Order	153	110	85	70	55	51	42	40	36	33	30	28
Center frequency	22%	23%	24%	25%	26%	27%	28%	29%	30%			
Order	26	24	23	21	20	19	18	17	16			

FIR–BPF order, bandwidth: 20%

Center frequency	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%
Order	192	128	96	77	64	55	48	43	38	35	32	29
Center frequency	24%	25%	26%	27%	28%	29%	30%					
Order	27	25	24	22	21	20	18					

FIR–BSF order, bandwidth: 5%

Center frequency	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%
Order	100	100	100	100	100	100	100	100	100	100	100	100
Center frequency	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%
Order	100	100	100	100	100	100	100	100	100	100	100	100
Center frequency	27%	28%	29%	30%								
Order	100	100	100	100								

FIR–BSF order, bandwidth: 10%

Center frequency	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%
Order	50	50	50	50	50	50	50	50	50	50	50	50
Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	50	50	50	50	50	50	50	50	50	50	50	50
Center frequency	29%	30%										
Order	50	50										

FIR–BSF order, bandwidth: 15%

Center frequency	8%	9%	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%
Order	34	34	34	34	34	34	34	34	34	34	34	34
Center frequency	20%	21%	22%	23%	24%	25%	26%	27%	28%	29%	30%	
Order	34	34	34	34	34	34	34	34	34	34	34	

FIR–BSF order, bandwidth: 20%

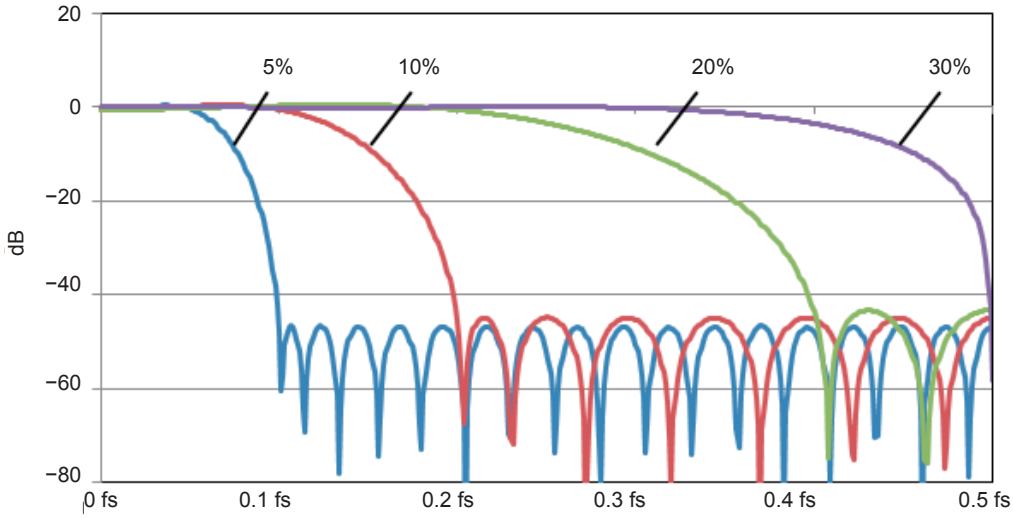
Center frequency	10%	11%	12%	13%	14%	15%	16%	17%	18%	19%	20%	21%
Order	26	26	26	26	26	26	26	26	26	26	26	26
Center frequency	22%	23%	24%	25%	26%	27%	28%	29%	30%			
Order	26	26	26	26	26	26	26	26	26			

Group delay time

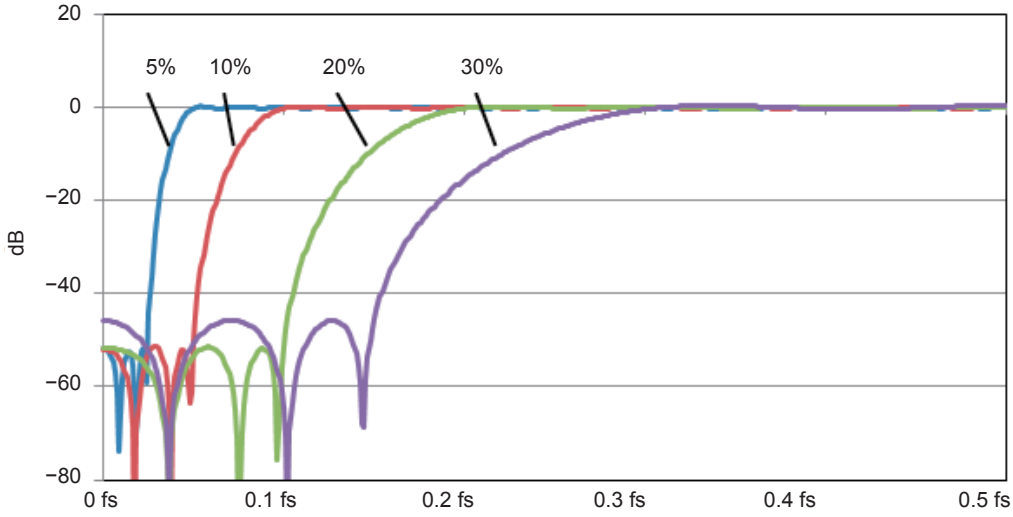
Group delay time = Order × T / 2
Where the T is the calculation update interval.

Example of LPF and HPF frequency characteristics diagram

Example of FIR–LPF frequency characteristics



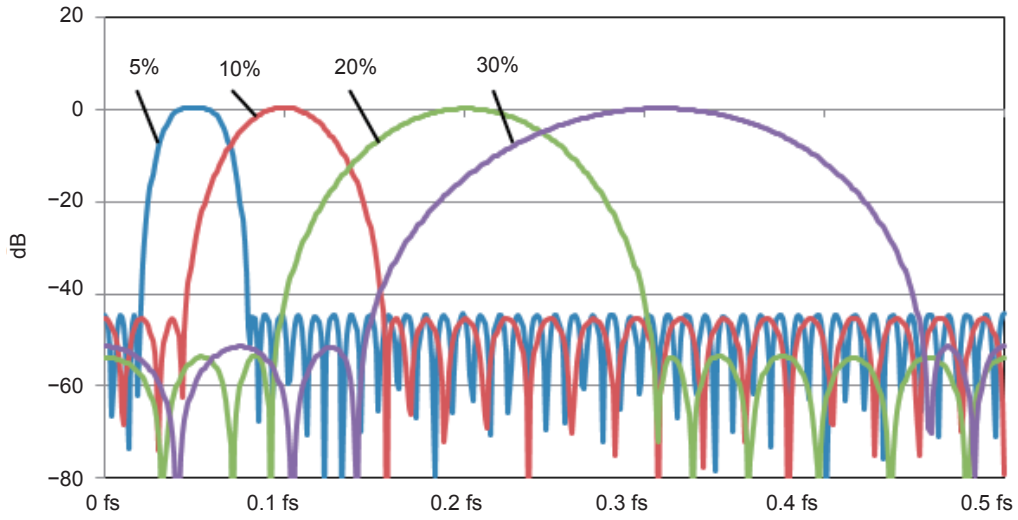
Example of FIR–HPF frequency characteristics



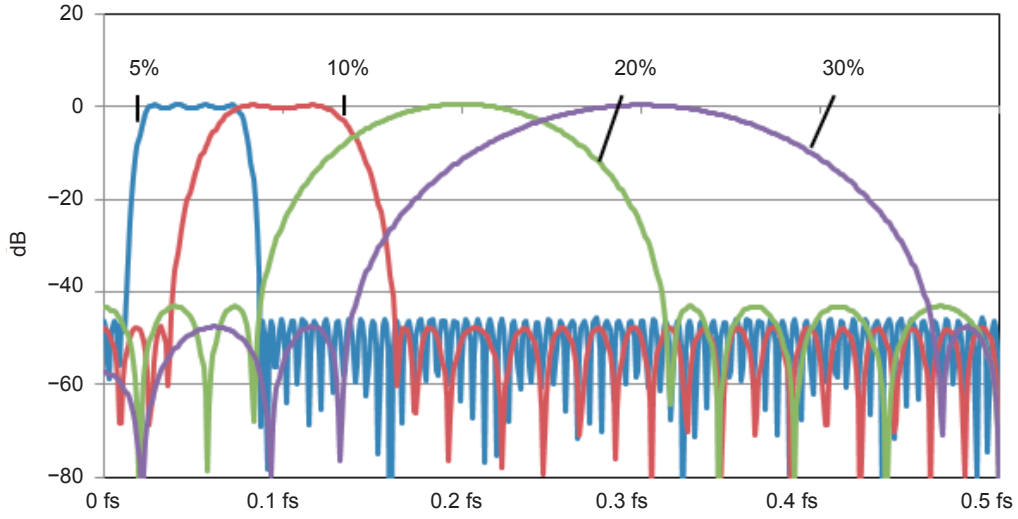
(fs: Calculation update rate [S/s])

Example of BPF frequency characteristics diagram

Example of FIR–BPF frequency characteristics (bandwidth: 2%)

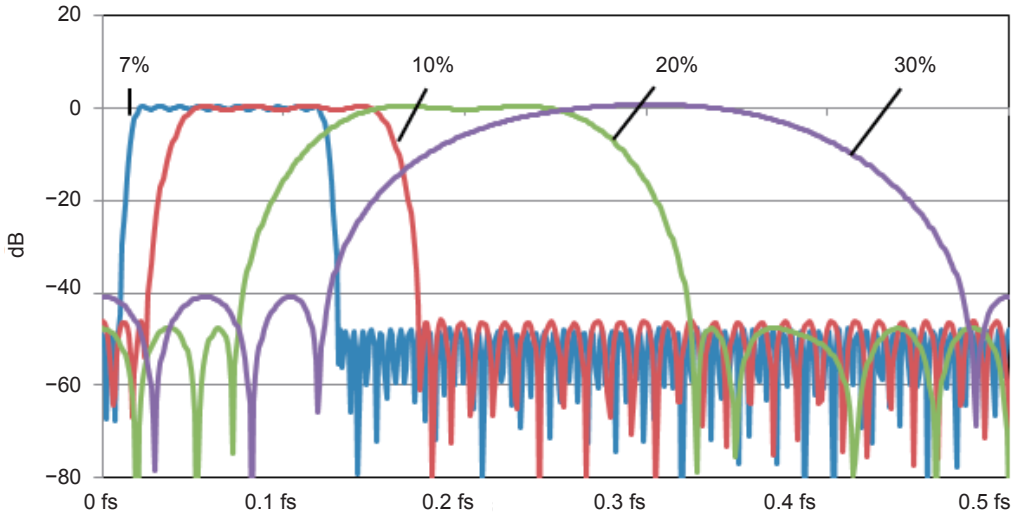


Example of FIR–BPF frequency characteristics (bandwidth: 5%)

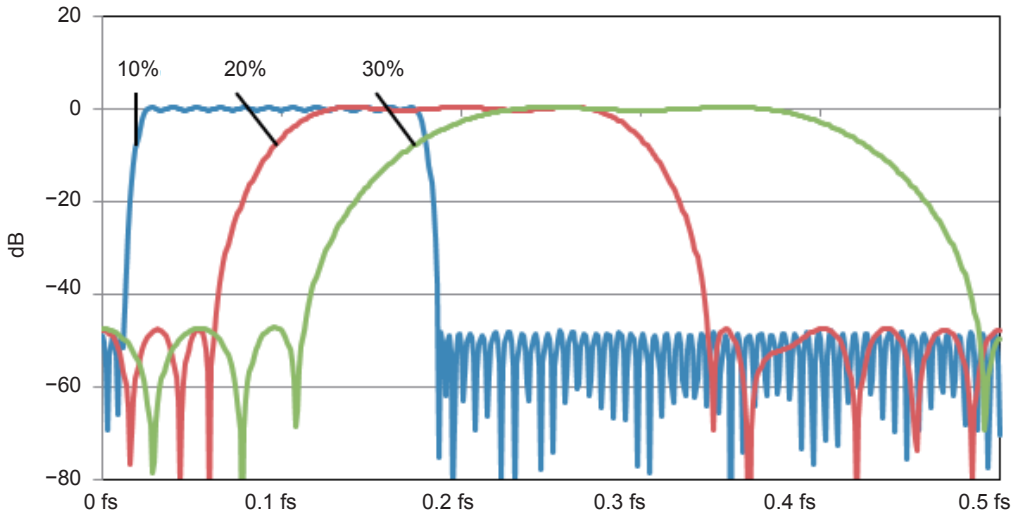


(fs: Calculation update rate [S/s])

Example of FIR–BPF frequency characteristics (bandwidth: 10%)

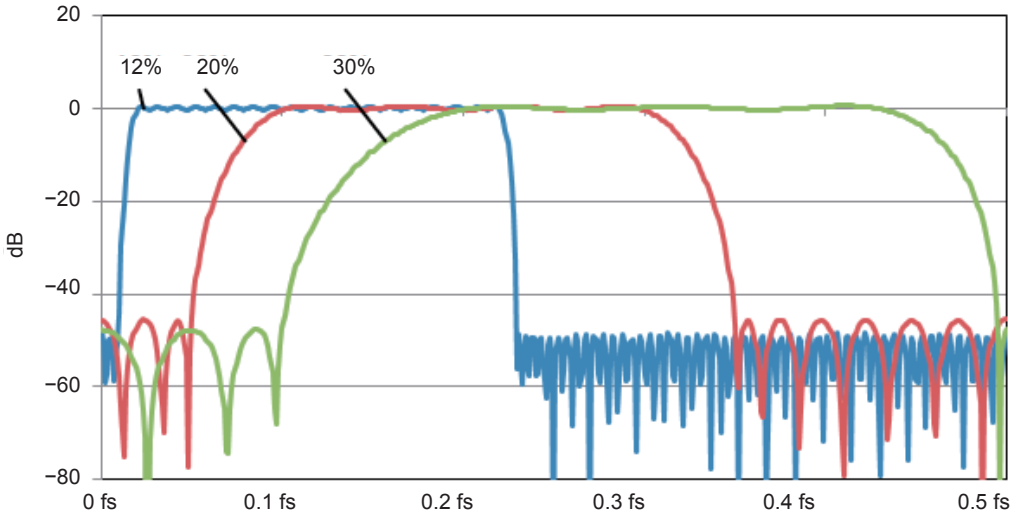


Example of FIR–BPF frequency characteristics (bandwidth: 15%)



(fs: Calculation update rate [S/s])

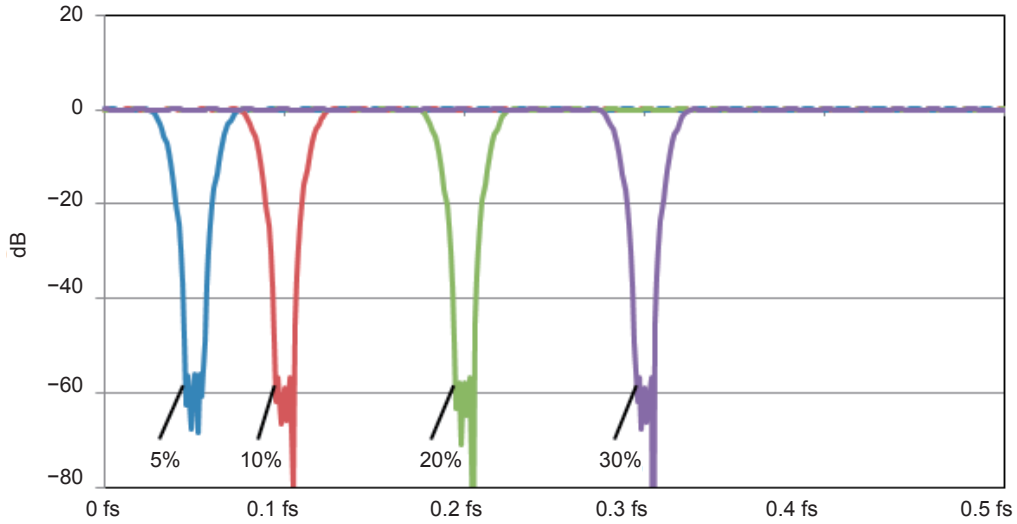
Example of FIR–BPF frequency characteristics (bandwidth: 20%)



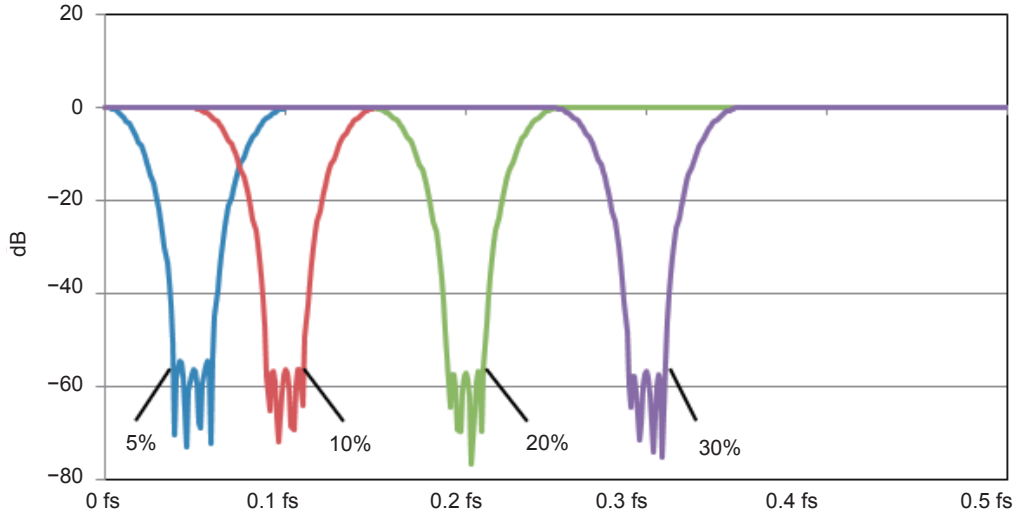
(fs: Calculation update rate [S/s])

Example of BSF frequency characteristics diagram

Example of FIR–BSF frequency characteristics (bandwidth: 5%)

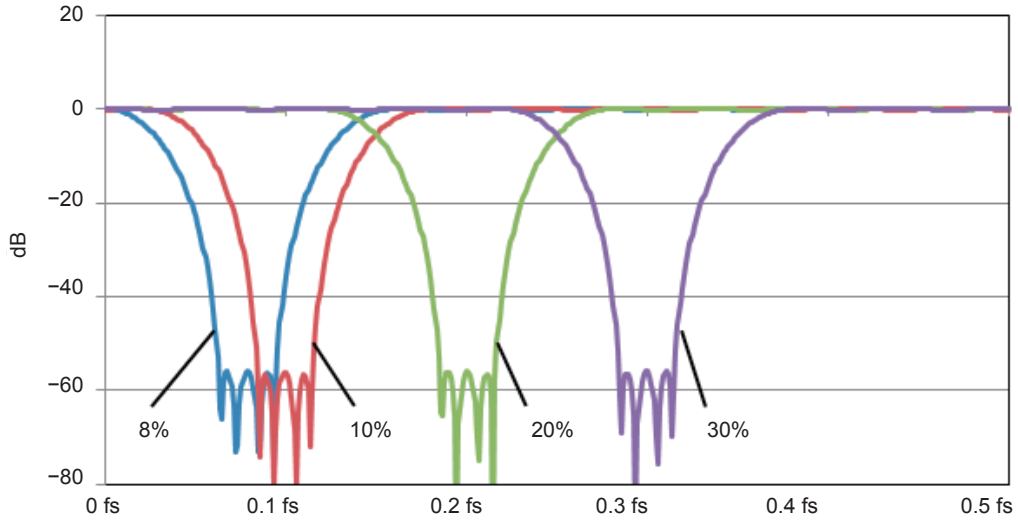


Example of FIR–BSF frequency characteristics (bandwidth: 10%)

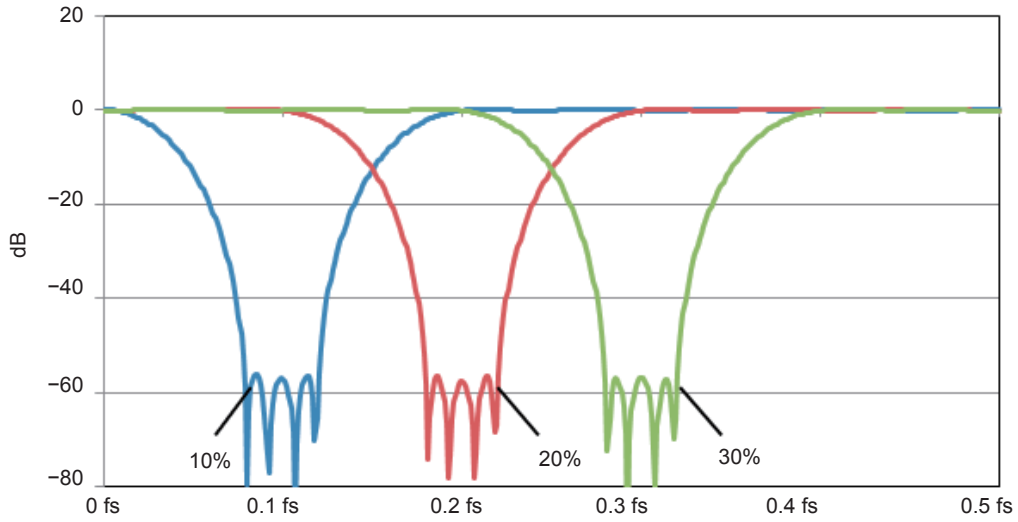


(fs: Calculation update rate [S/s])

Example of FIR–BSF frequency characteristics (bandwidth: 15%)



Example of FIR–BSF frequency characteristics (bandwidth: 20%)



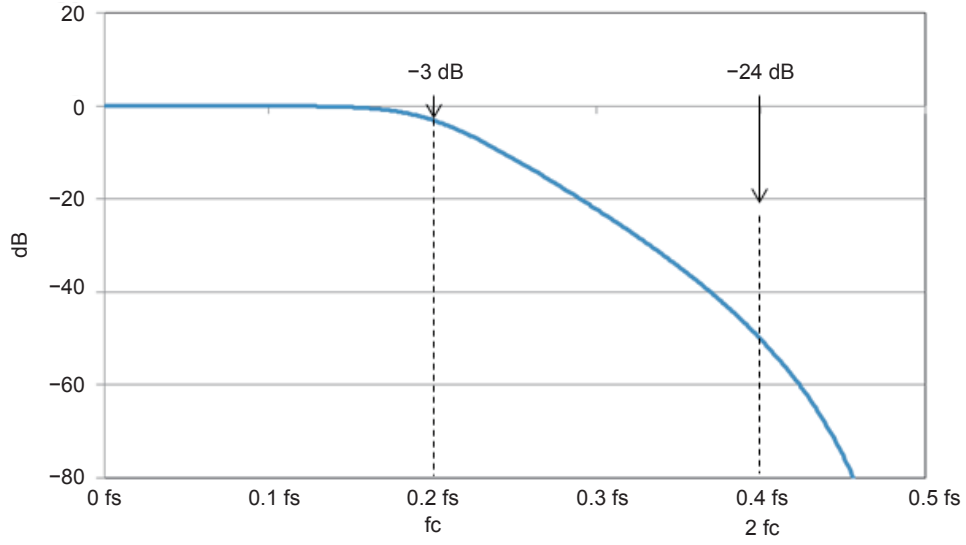
(fs: Calculation update rate [S/s])

3.5 IIR (Butterworth) Filter Characteristics

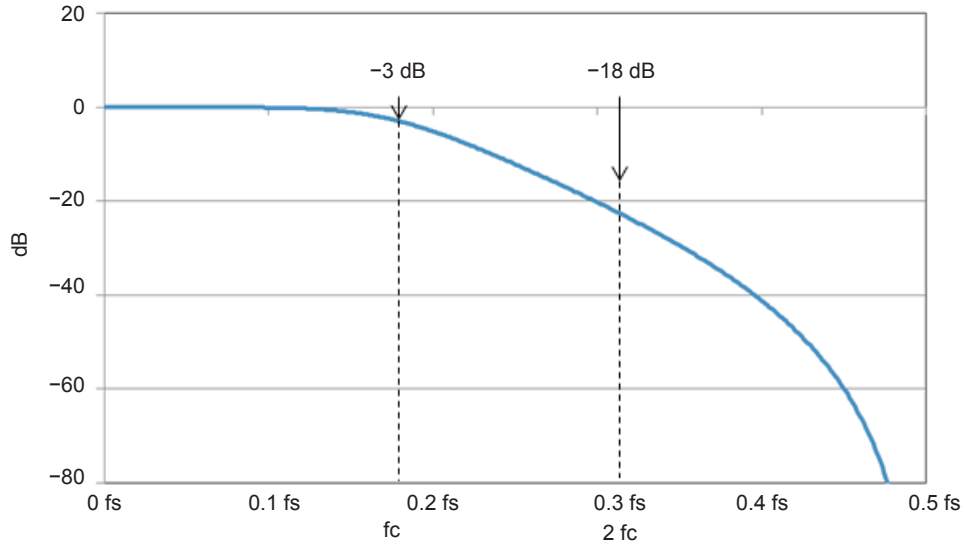
LPF and HPF characteristics

- Frequency characteristics within the pass band are flat.
- The attenuation at the cut-off frequency is −3 dB.
- The attenuation slope is (Order × −6) decibel.

Example of IIR–LPF (fourth order) frequency characteristics

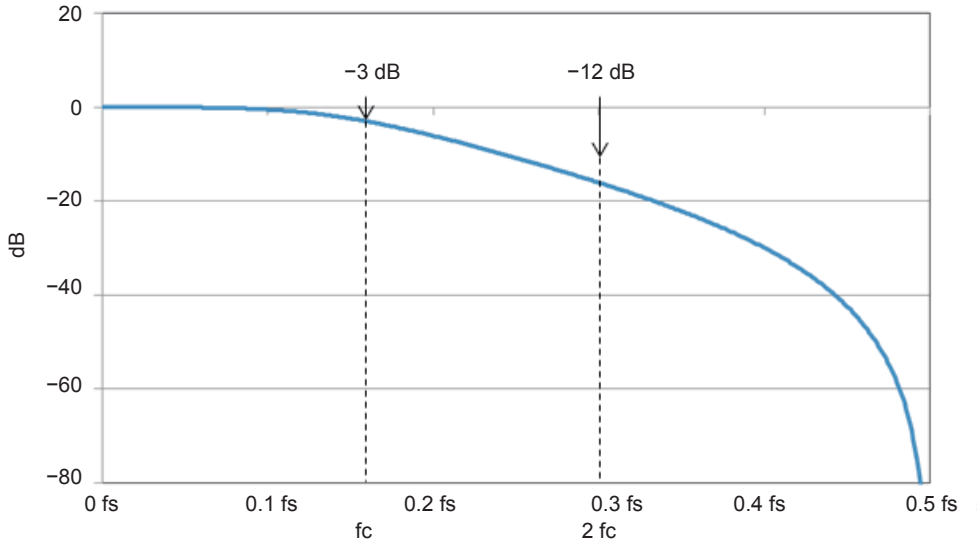


Example of IIR–LPF (third order) frequency characteristics

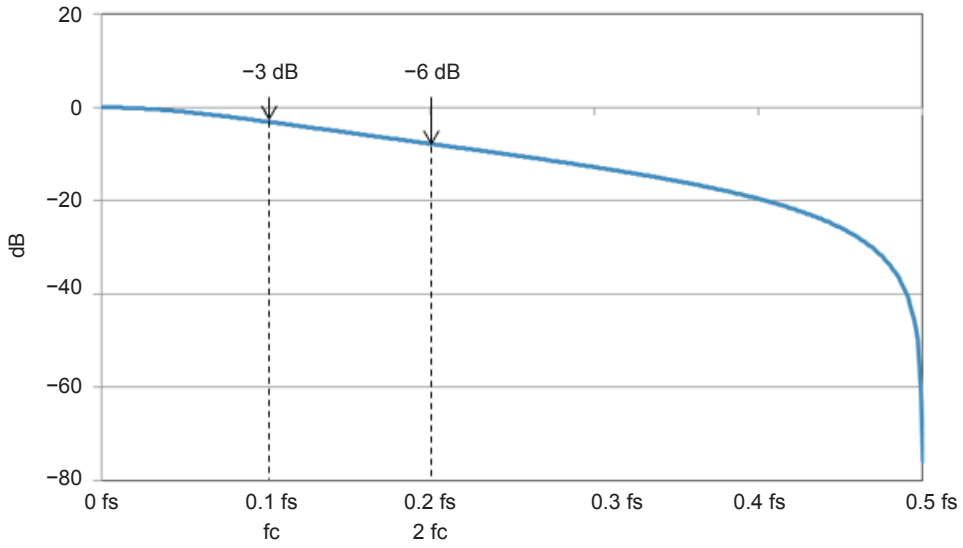


(fs: Calculation update rate [S/s])

Example of IIR–LPF (second order) frequency characteristics

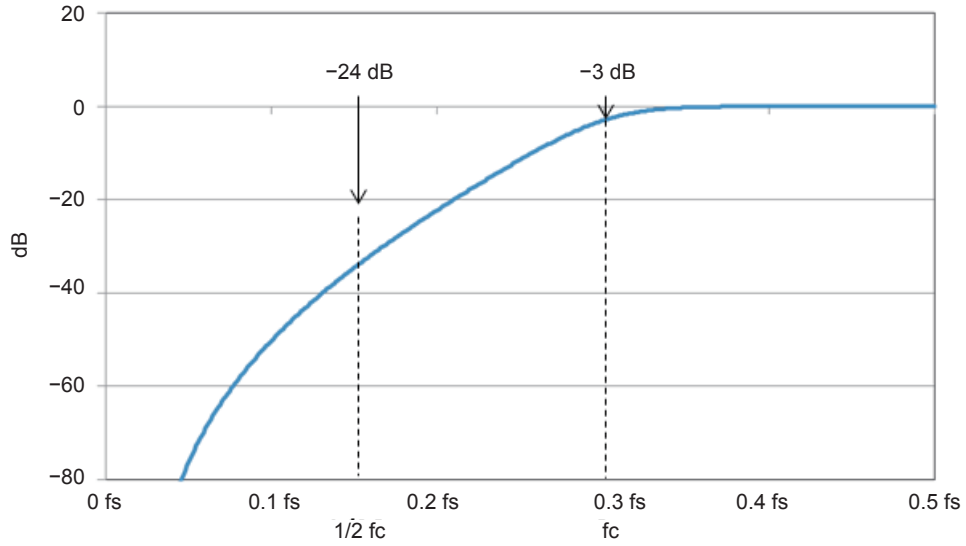


Example of IIR–LPF (first order) frequency characteristics

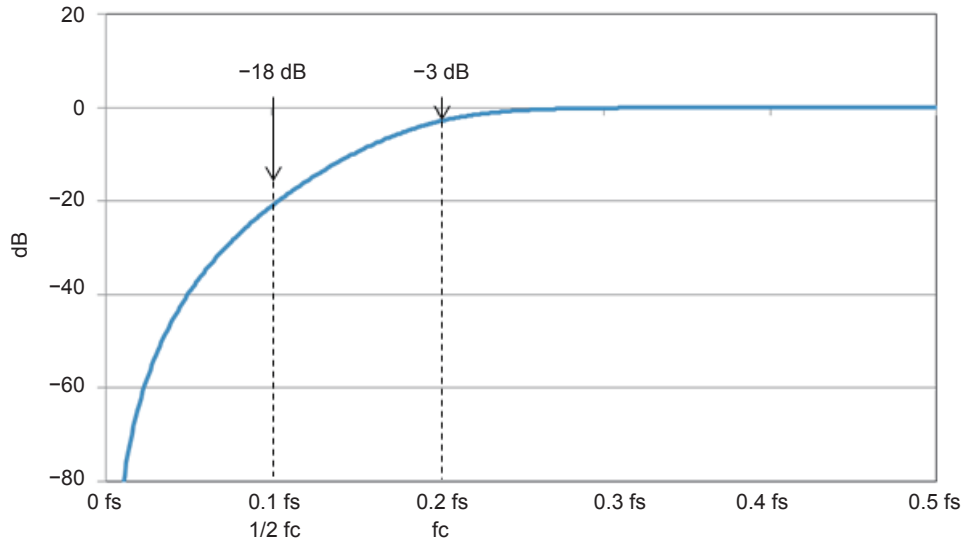


(fs: Calculation update rate [S/s])

Example of IIR–HPF (fourth order) frequency characteristics

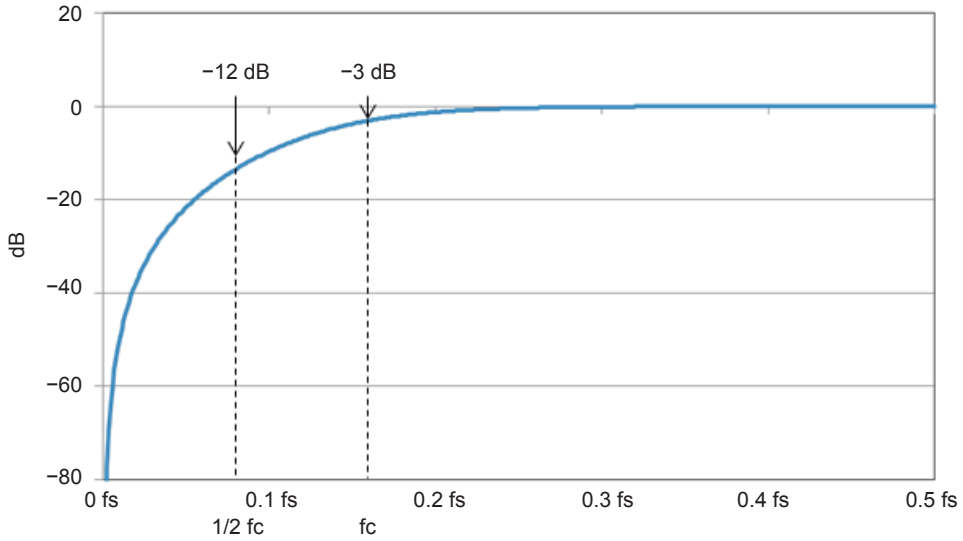


Example of IIR–HPF (third order) frequency characteristics

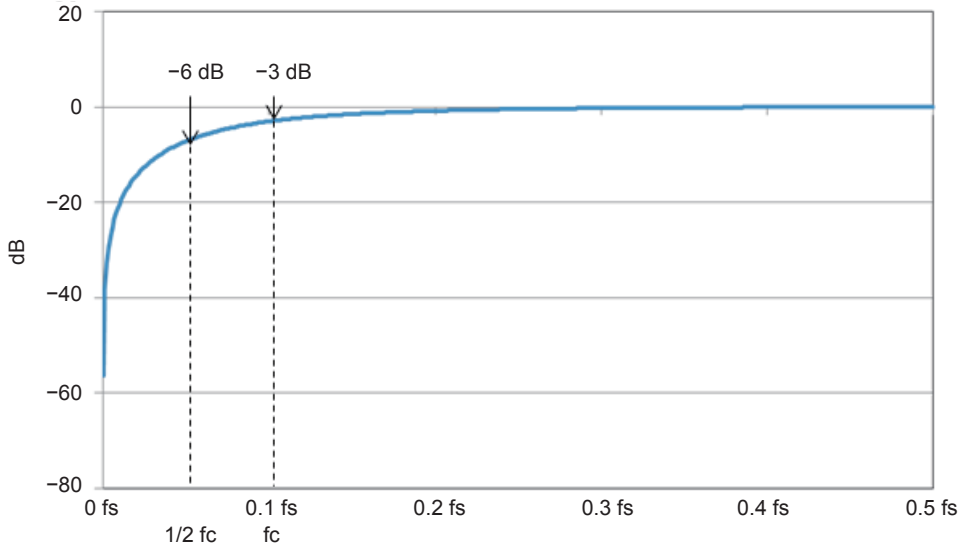


(fs: Calculation update rate [S/s])

Example of IIR–HPF (second order) frequency characteristics



Example of IIR–HPF (first order) frequency characteristics

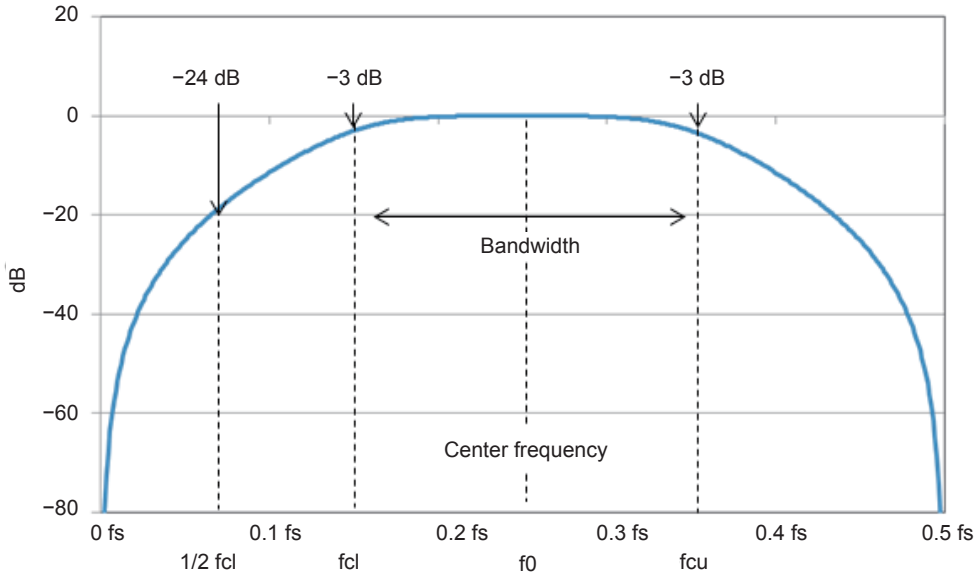


(fs: Calculation update rate [S/s])

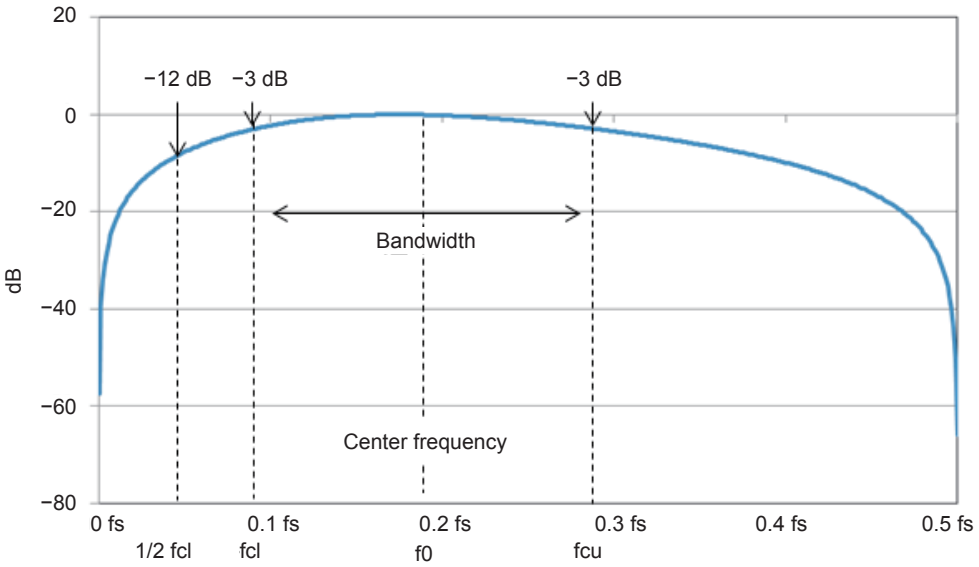
BPF characteristics

- Frequency characteristics within the pass band are flat.
- The attenuation at the cut-off frequency is −3 dB.
- The attenuation slope is (Order × −6) dB decibel.

Example of IIR–BPF (fourth order) frequency characteristics



Example of IIR–BPF (second order) frequency characteristics



(fs: Calculation update rate [S/s])

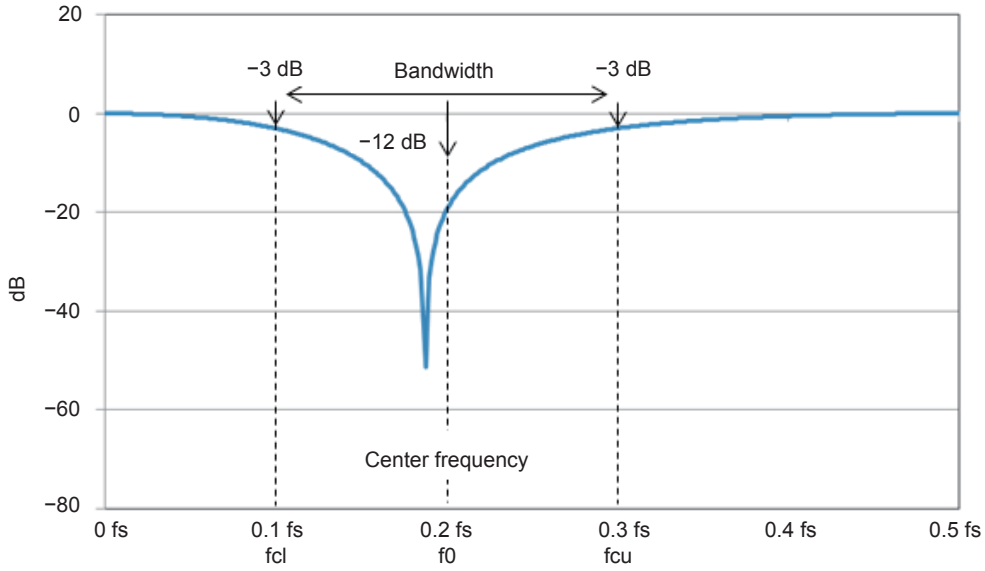
The bandwidth that can be set for the IIR band-pass filter varies depending on the center frequency.

Center frequency [Hz]	Frequency bandwidth [Hz]	Calculation update rate [S/s]
1.7 M to 3 M	100 k, 200 k, 500 k, 1 M, 1.5 M, 2 M	10 M
1.5 M, 1.6 M	1 M, 1.5 M, 2 M	10 M
1.4 M	1.5 M, 2 M	10 M
1.3 M	2 M	10 M
170 k to 300 k	10 k, 20 k, 50 k, 100 k, 150 k, 200 k	1 M
150 k, 160 k	100 k, 150 k, 200 k	1 M
140 k	150 k, 200 k	1 M
130 k	200 k	1 M
17 k to 30 k	1 k, 2 k, 5 k, 10 k, 15 k, 20 k	100 k
15 k, 16 k	10 k, 15 k, 20 k	100 k
14 k	15 k, 20 k	100 k
13 k	20 k	100 k

BSF characteristics

- Frequency characteristics within the pass band are flat.
- The attenuation at the cut-off frequency is −3 dB.
- The attenuation slope is (Order × −6) decibel.

Example of IIR–BSF (second order) frequency characteristics



The bandwidth that can be set for the IIR band-stop filter varies depending on the center frequency.

Center frequency [Hz]	Frequency bandwidth [Hz]	Calculation update rate [S/s]
1.7 M to 3 M	100 k, 200 k, 500 k, 1 M, 1.5 M, 2 M	10 M
1.6 M	500 k, 1 M, 1.5 M, 2 M	10 M
1.5 M	1 M, 1.5 M, 2 M	10 M
1.4 M	1.5 M, 2 M	10 M
1.3 M	2 M	10 M
170 k to 300 k	10 k, 20 k, 50 k, 100 k, 150 k, 200 k	1 M
160 k	50 k, 100 k, 150 k, 200 k	1 M
150 k	100 k, 150 k, 200 k	1 M
140 k	150 k, 200 k	1 M
130 k	200 k	1 M
17 k to 30 k	1 k, 2 k, 5 k, 10 k, 15 k, 20 k	100 k
16 k	5 k, 10 k, 15 k, 20 k	100 k
15 k	10 k, 15 k, 20 k	100 k
14 k	15 k, 20 k	100 k
13 k	20 k	100 k

Filter order

The orders of the IIR filter are as follows. The cut-off frequencies and center frequencies are expressed as ratios of the calculation update rate in terms with percent.

IIR–LPF order

Cut-off frequency	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	0.9%	1%	2%	3%	4%
Order	1	1	1	1	1	1	1	1	1	1	1	1
Cut-off frequency	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%
Order	1	1	1	1	1	1	1	2	2	2	2	2
Cut-off frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	3	3	4	4	4	4	4	4	4	4	4	4
Cut-off frequency	29%	30%										
Order	4	4										

IIR–HPF order

Cut-off frequency	0.2%	0.3%	0.4%	0.5%	0.6%	0.7%	0.8%	0.9%	1%	2%	3%	4%
Order	1	1	1	1	1	1	1	1	1	1	1	1
Cut-off frequency	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%	15%	16%
Order	1	1	1	1	1	1	1	1	1	1	1	2
Cut-off frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	3	3	3	3	4	4	4	4	4	4	4	4
Cut-off frequency	29%	30%										
Order	4	4										

IIR–BPF order, bandwidth: 1%

Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	29%	30%										
Order	2	2										

IIR–BPF order, bandwidth: 2%

Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	29%	30%										
Order	2	2										

IIR–BPF order, bandwidth: 5%

Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	29%	30%										
Order	2	2										

IIR–BPF order, bandwidth: 10%

Center frequency	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	27%	28%	29%	30%								
Order	2	2	2	2								

IIR–BPF order, bandwidth: 15%

Center frequency	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%
Order	2	2	2	2	2	2	4	4	4	4	4	4
Center frequency	26%	27%	28%	29%	30%							
Order	4	4	4	4	4							

IIR–BPF order, bandwidth: 20%

Center frequency	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%
Order	2	2	2	2	2	2	2	4	4	4	4	4
Center frequency	25%	26%	27%	28%	29%	30%						
Order	4	4	4	4	4	4						

IIR–BSF order, bandwidth: 1%

Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	29%	30%										
Order	2	2										

IIR–BSF order, bandwidth: 2%

Center frequency	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%	28%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	29%	30%										
Order	2	2										

IIR–BSF order, bandwidth: 5%

Center frequency	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%	27%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	28%	29%	30%									
Order	2	2	2									

IIR–BSF order, bandwidth: 10%

Center frequency	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%	26%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	27%	28%	29%	30%								
Order	2	2	2	2								

IIR–BSF order, bandwidth: 15%

Center frequency	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%	25%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	26%	27%	28%	29%	30%							
Order	2	2	2	2	2							

IIR–BSF order, bandwidth: 20%

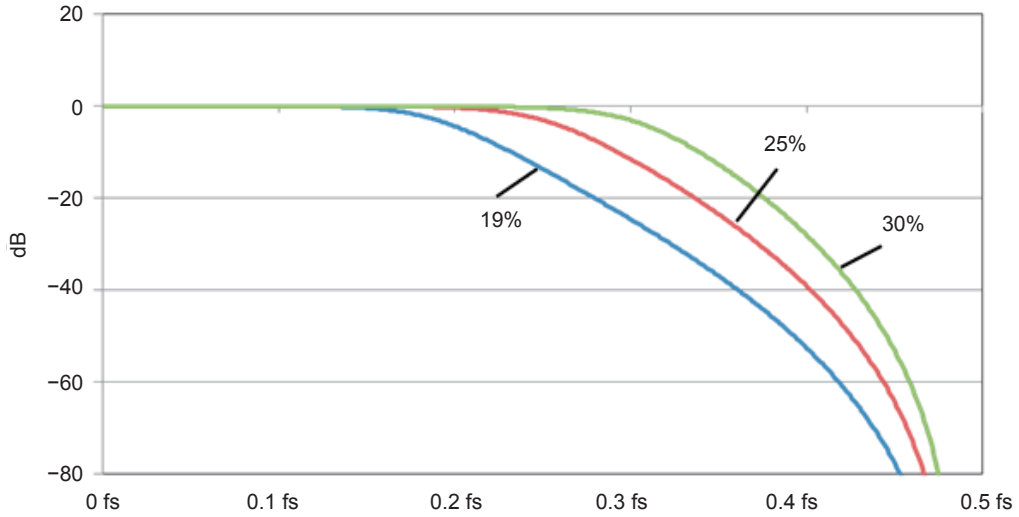
Center frequency	13%	14%	15%	16%	17%	18%	19%	20%	21%	22%	23%	24%
Order	2	2	2	2	2	2	2	2	2	2	2	2
Center frequency	25%	26%	27%	28%	29%	30%						
Order	2	2	2	2	2	2						

Group delay time

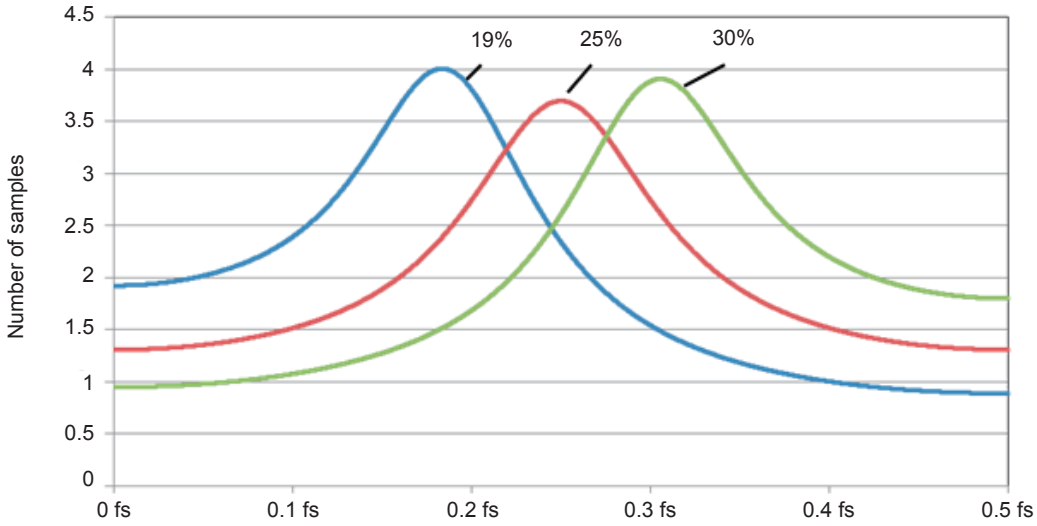
Since the IIR filters have non-linear phase characteristics, their group delay cannot be uniquely determined and varies depending on the frequency.
The group delay time is calculated by the following equation:
Group delay time = Number of group delay samples × Calculation update interval

Examples of LPF frequency characteristics diagram and group delay characteristics diagram

Example of IIR–LPF (fourth order) frequency characteristics

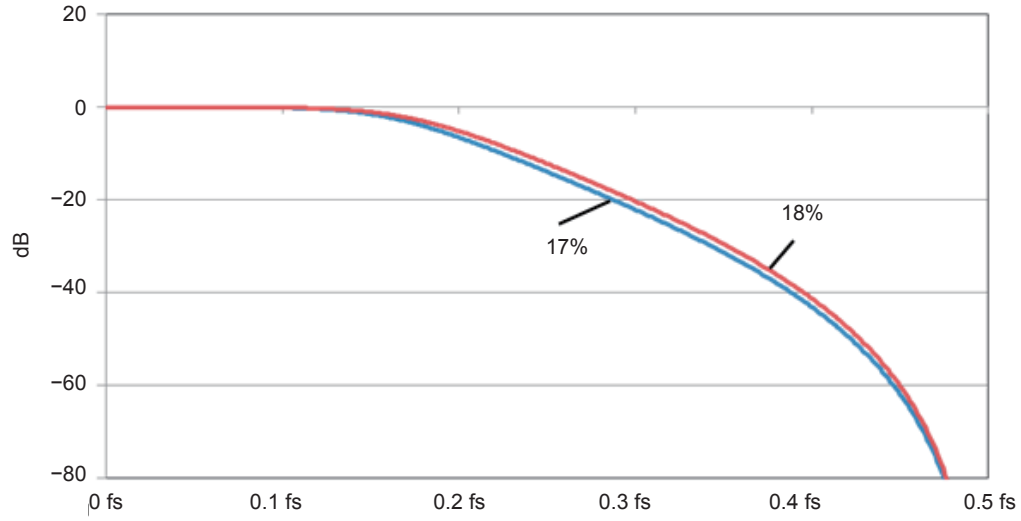


Example of IIR–LPF (fourth order) group delay characteristics

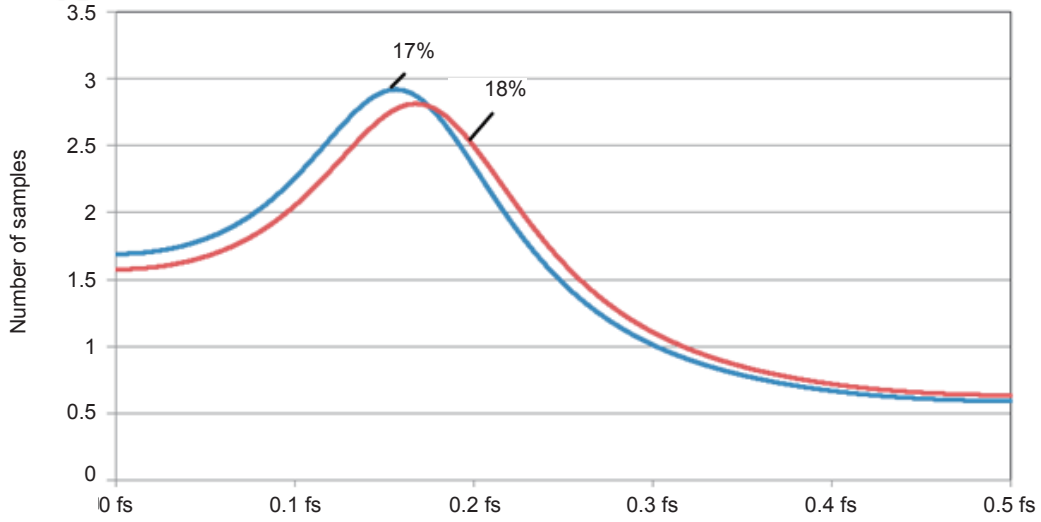


(fs: Calculation update rate [S/s])

Example of IIR–LPF (third order) frequency characteristics

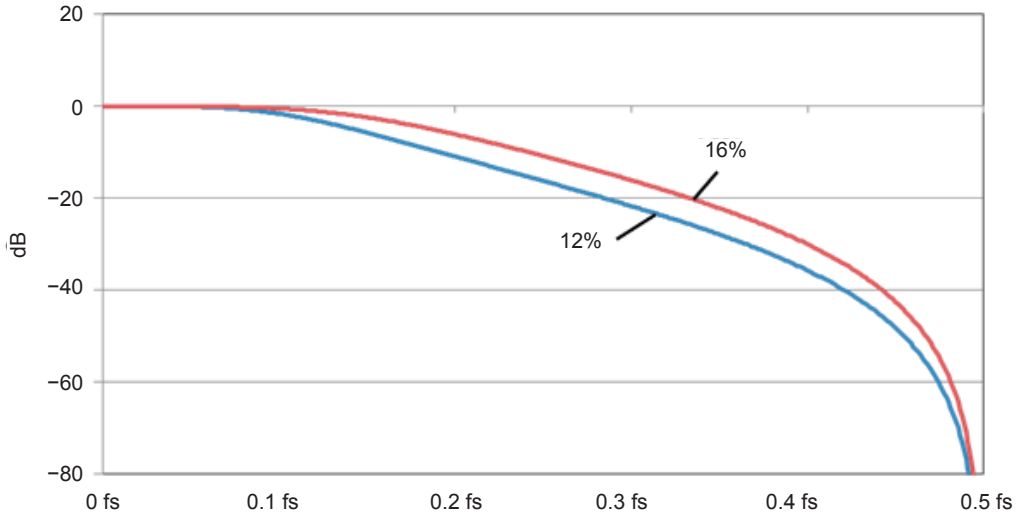


Example of IIR–LPF (third order) group delay characteristics

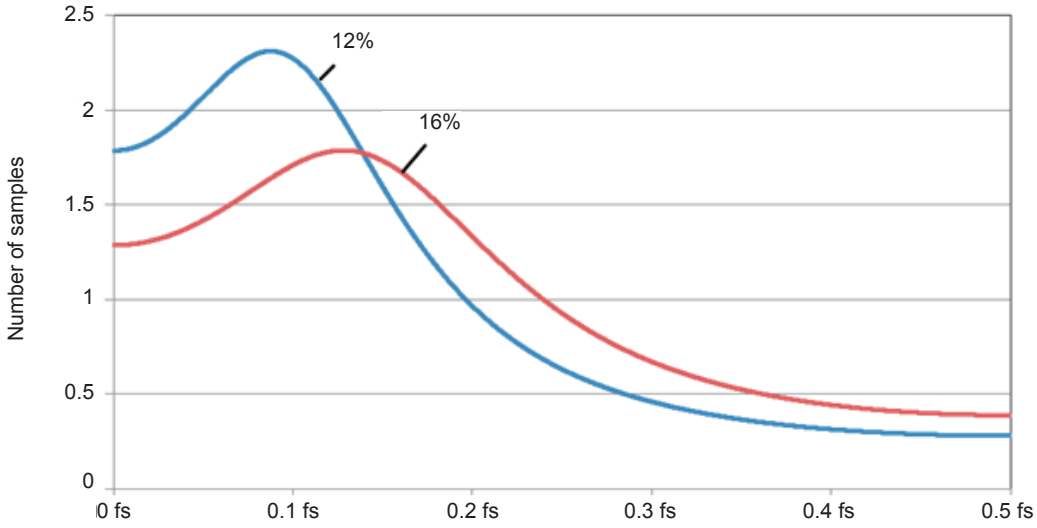


(fs: Calculation update rate [S/s])

Example of IIR–LPF (second order) frequency characteristics

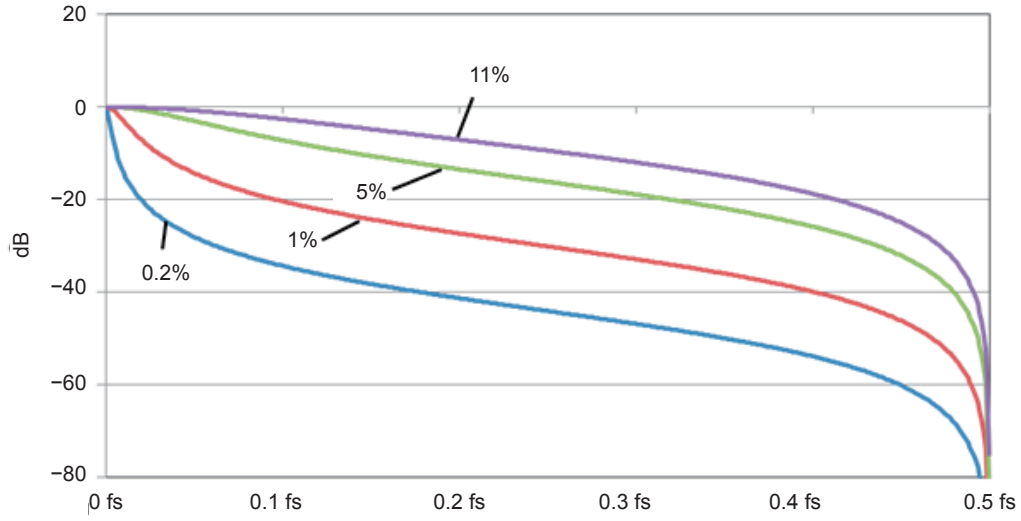


Example of IIR–LPF (second order) group delay characteristics

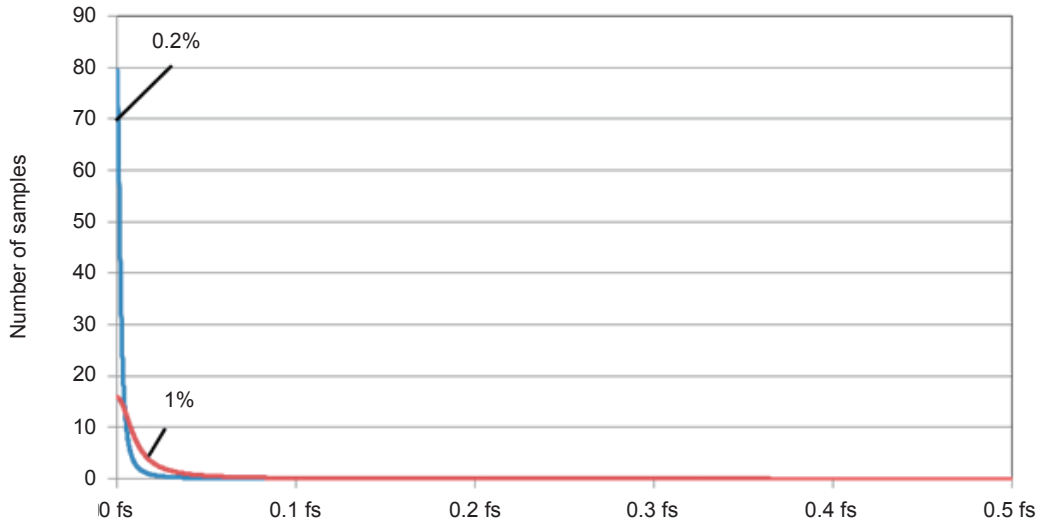


(fs: Calculation update rate [S/s])

Example of IIR–LPF (first order) frequency characteristics

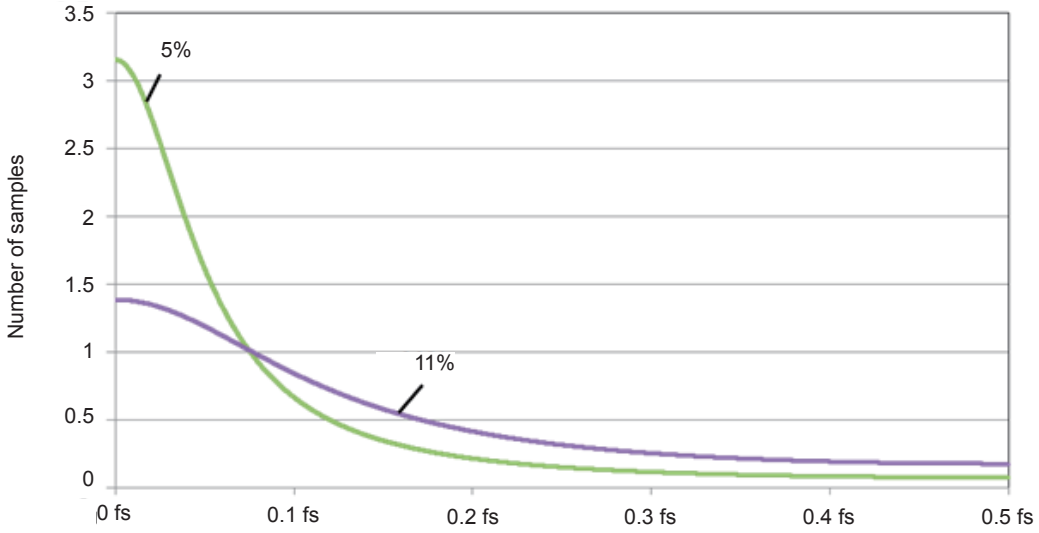


Example of IIR–LPF (first order) group delay characteristics (1)



(fs: Calculation update rate [S/s])

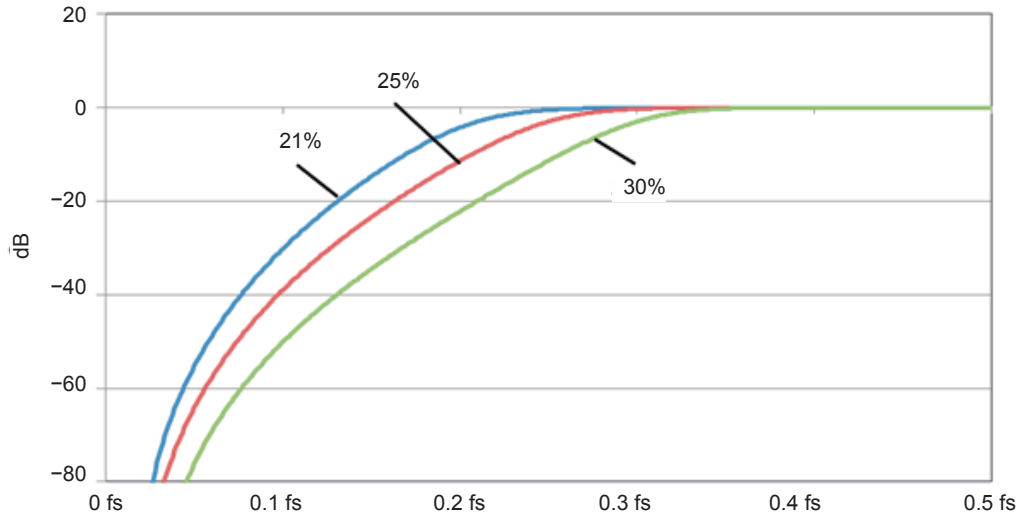
Example of IIR–LPF (first order) group delay characteristics (2)



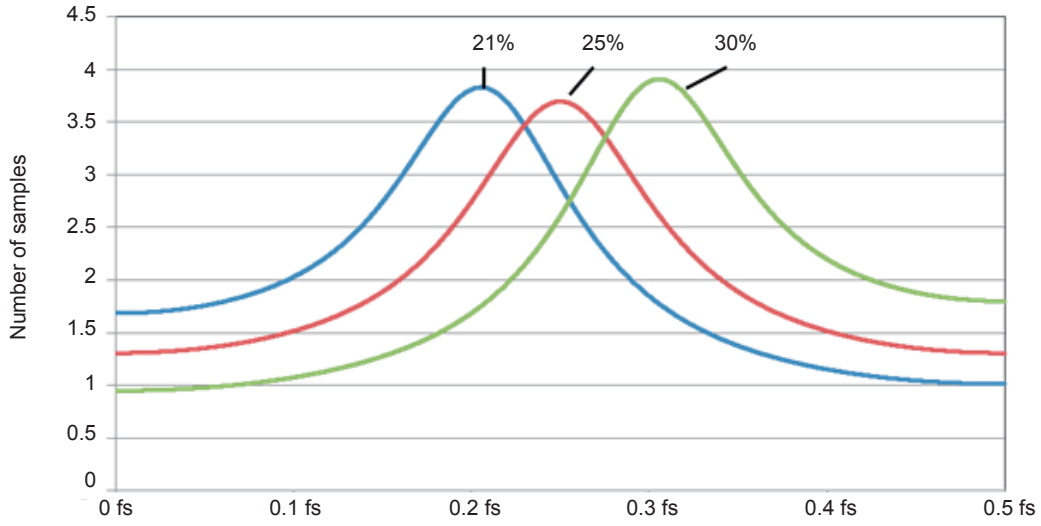
(fs: Calculation update rate [S/s])

Examples of HPF frequency characteristics diagram and group delay characteristics diagram

Example of IIR–HPF (fourth order) frequency characteristics

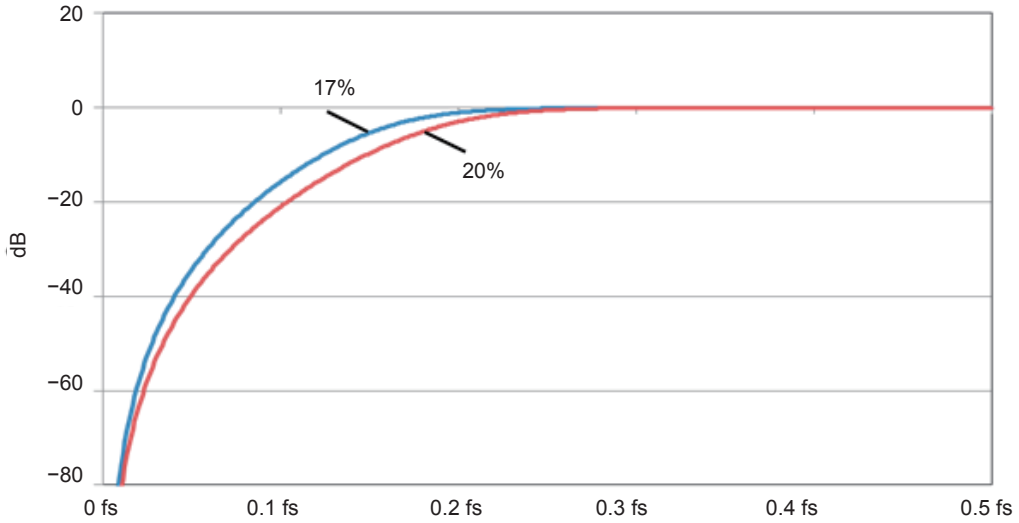


Example of IIR–HPF (fourth order) group delay characteristics

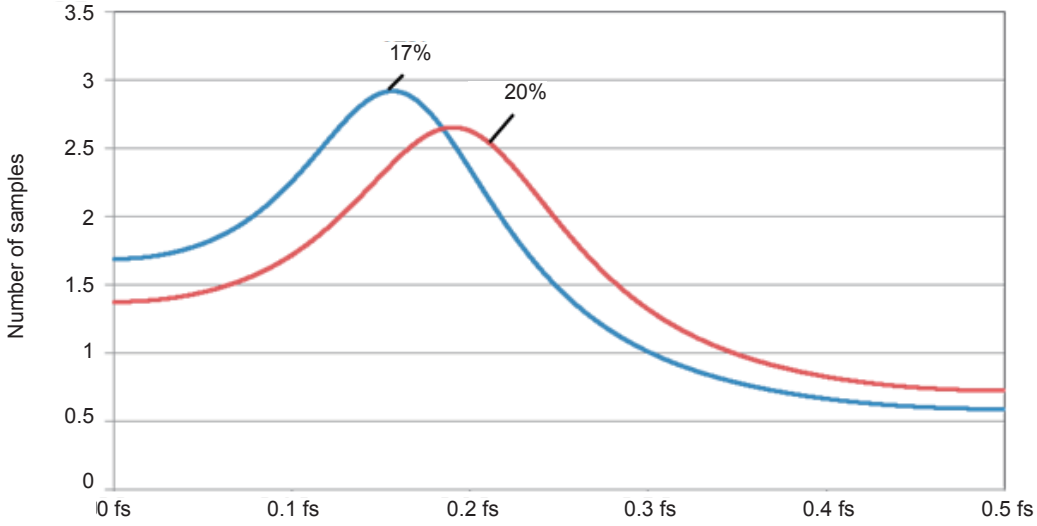


(fs: Calculation update rate [S/s])

Example of IIR–HPF (third order) frequency characteristics

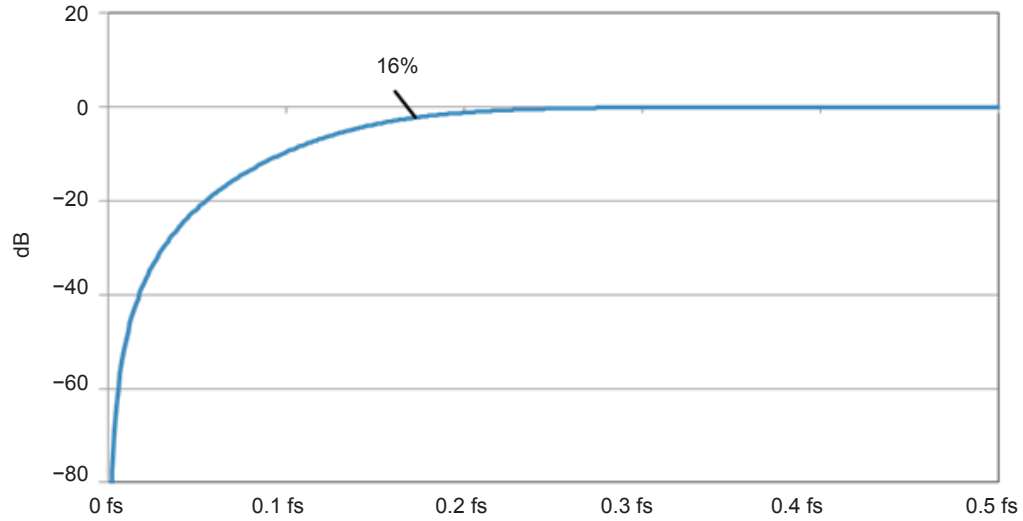


Example of IIR–HPF (third order) group delay characteristics

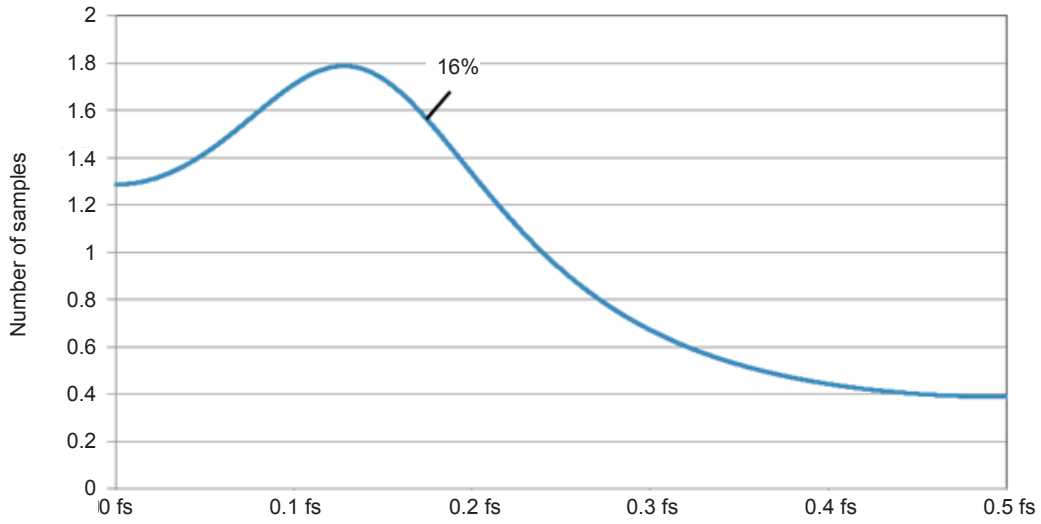


(fs: Calculation update rate [S/s])

Example of IIR–HPF (second order) frequency characteristics

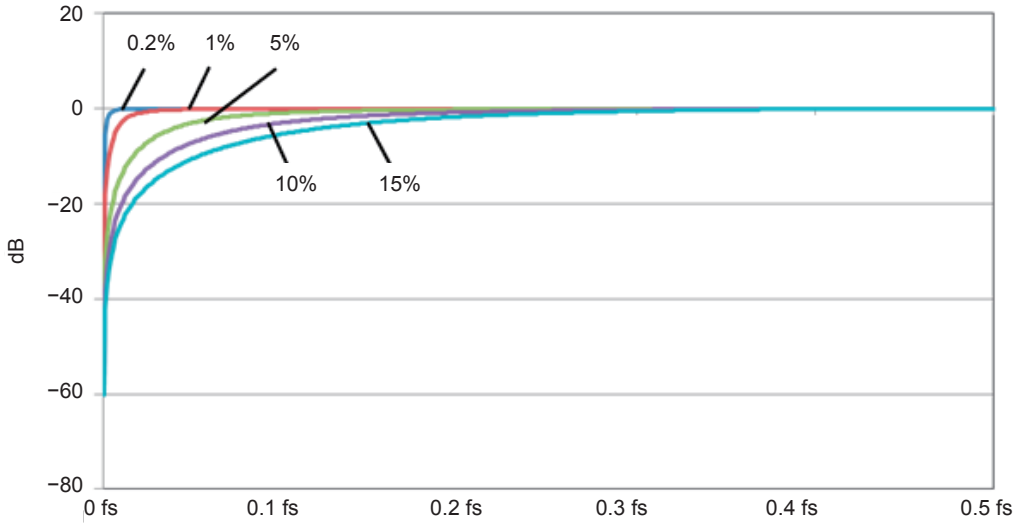


Example of IIR–HPF (second order) group delay characteristics

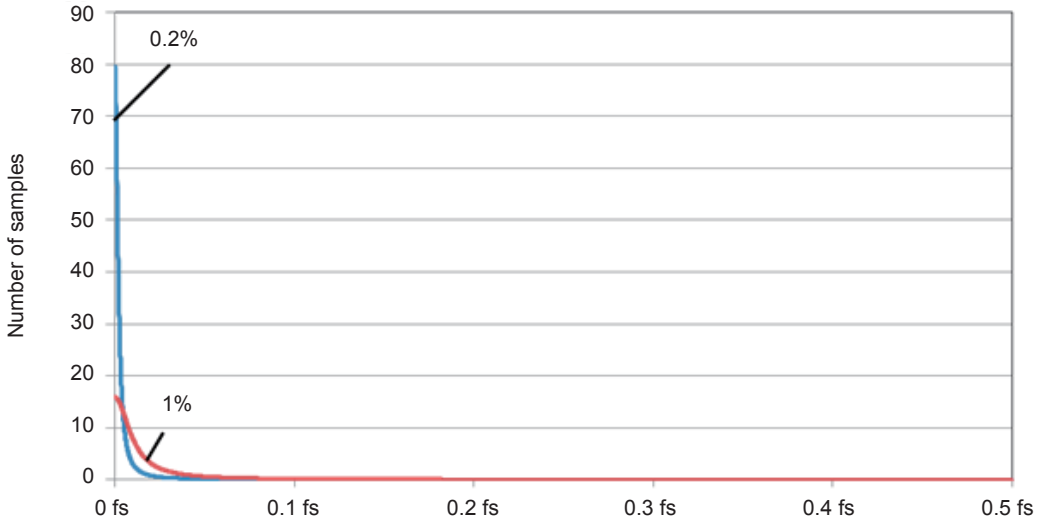


(fs: Calculation update rate [S/s])

Example of IIR–HPF (first order) frequency characteristics

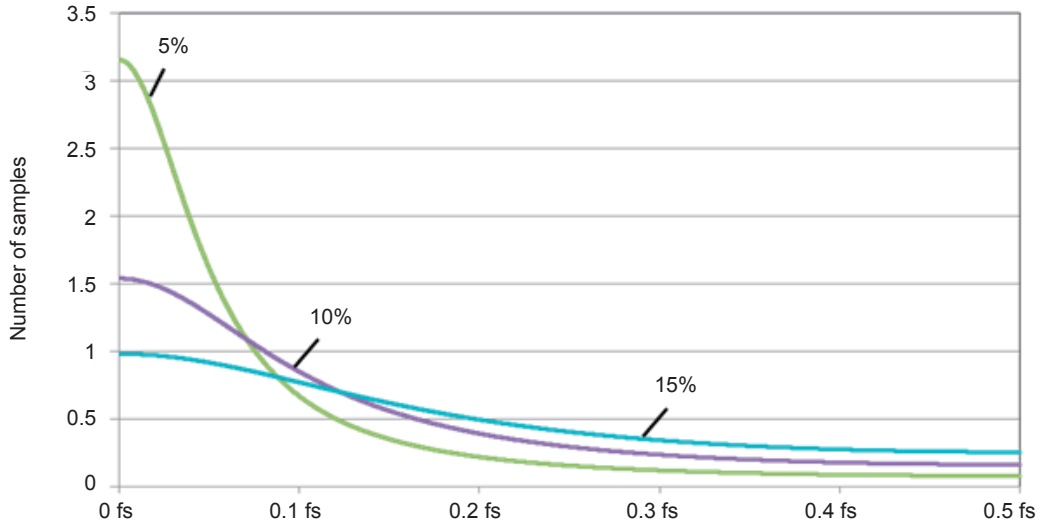


Example of IIR–HPF (first order) group delay characteristics (1)



(fs: Calculation update rate [S/s])

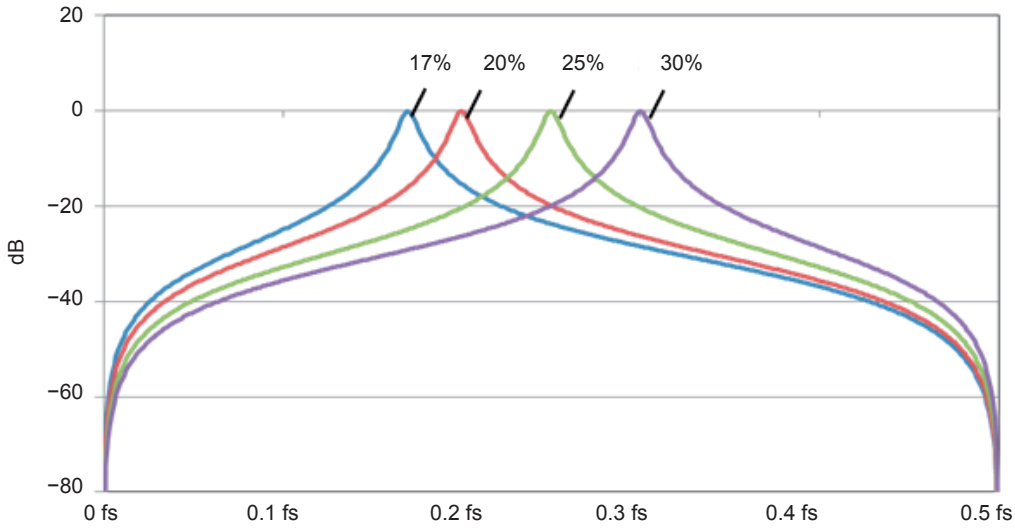
Example of IIR–HPF (first order) group delay characteristics (2)



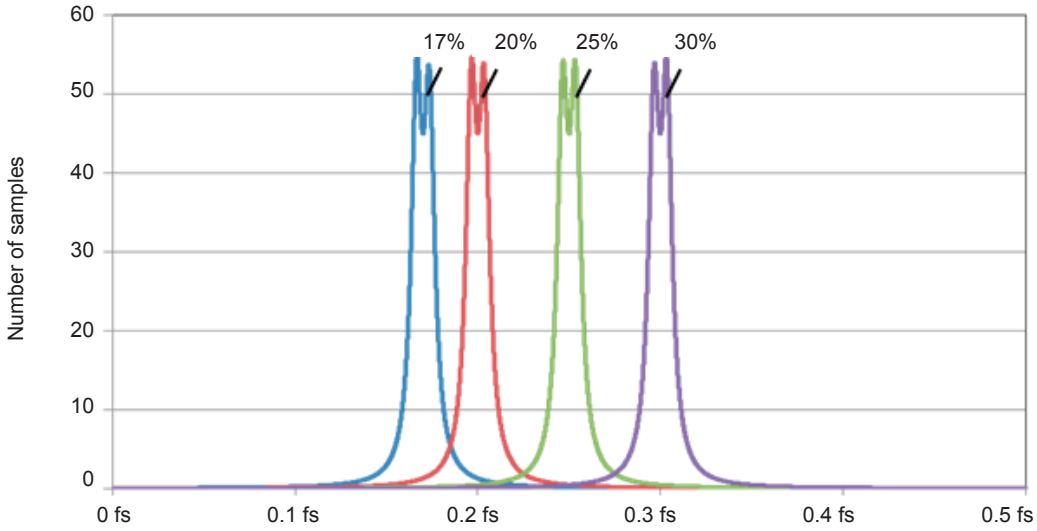
(fs: Calculation update rate [S/s])

Examples of BPF frequency characteristics diagram and group delay characteristics diagram

Example of IIR–BPF (second order) frequency characteristics (bandwidth: 1%)

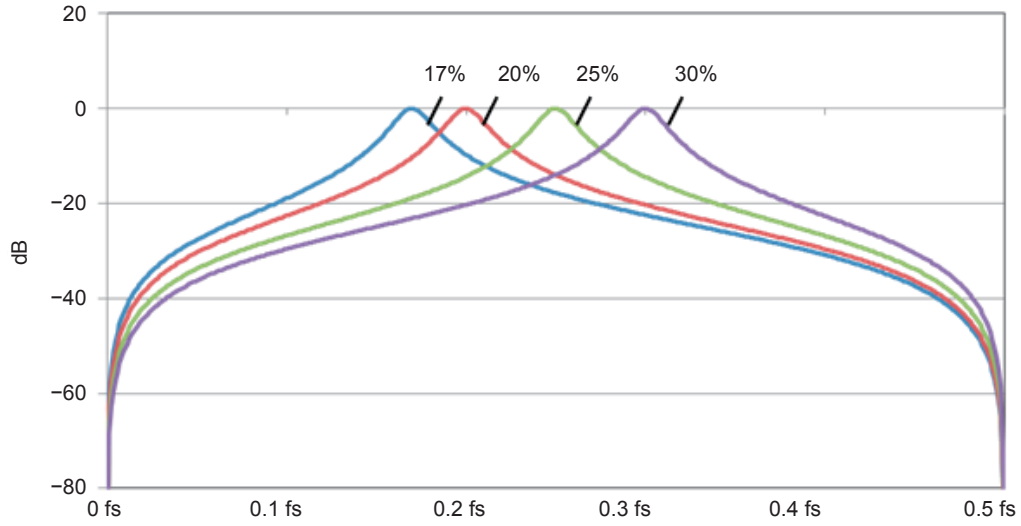


Example of IIR–BPF (second order) group delay characteristics (bandwidth: 1%)

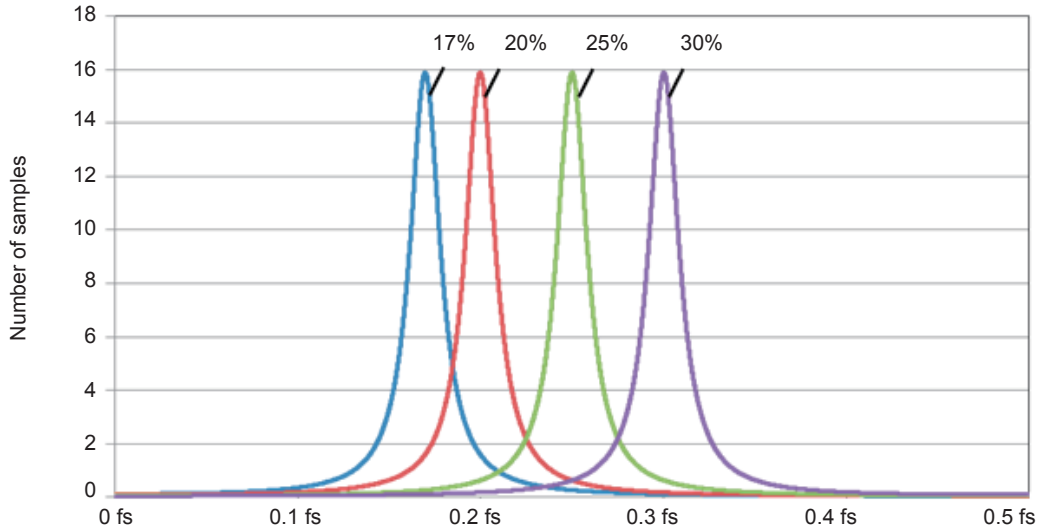


(fs: Calculation update rate [S/s])

Example of IIR–BPF (second order) frequency characteristics (bandwidth: 2%)

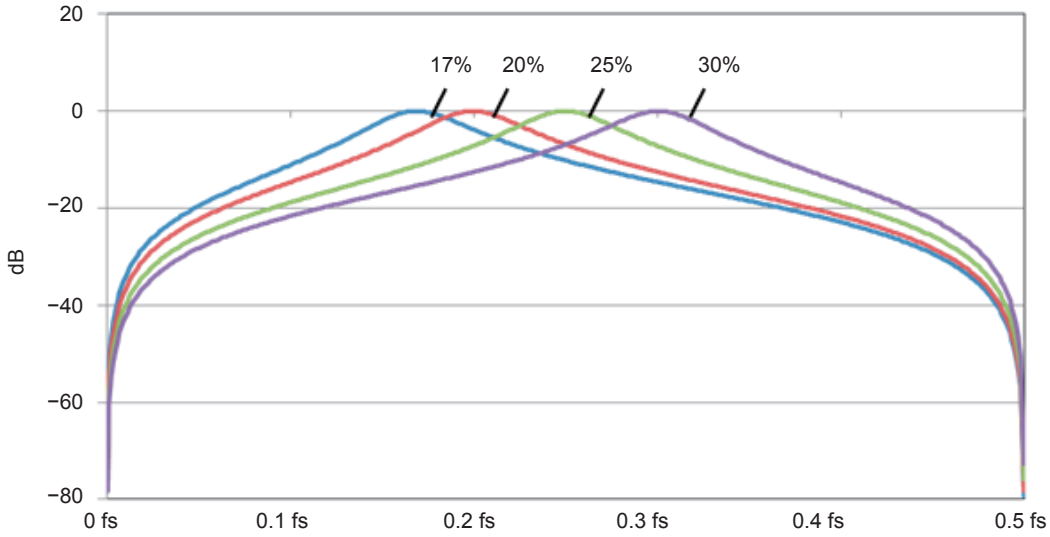


Example of IIR–BPF (second order) group delay characteristics (bandwidth: 2%)

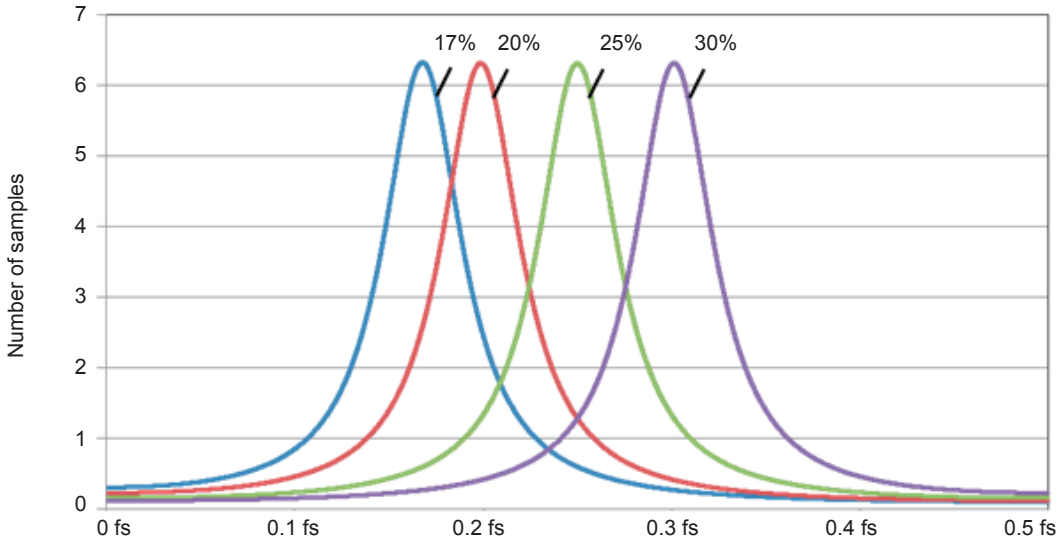


(fs: Calculation update rate [S/s])

Example of IIR–BPF (second order) frequency characteristics (bandwidth: 5%)

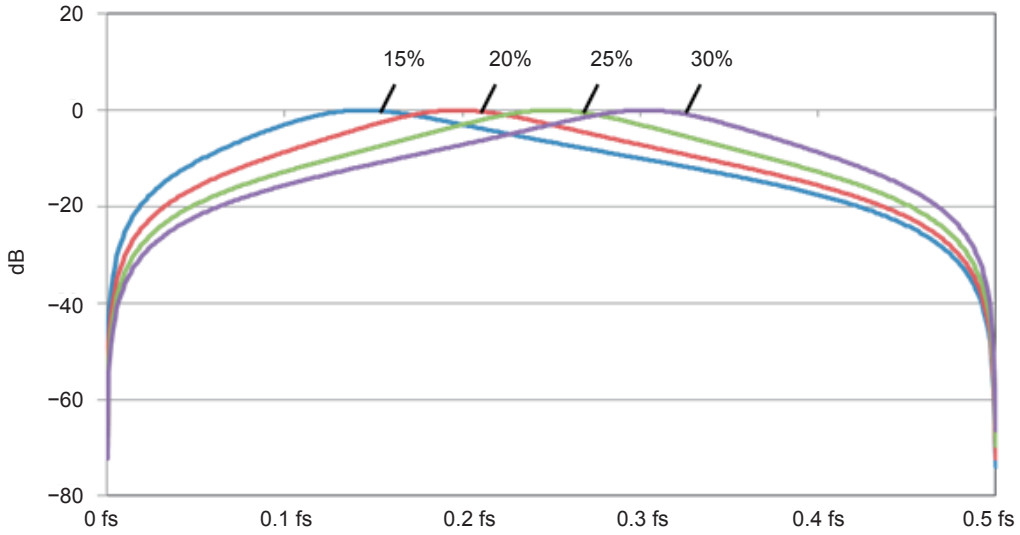


Example of IIR–BPF (second order) group delay characteristics (bandwidth: 5%)

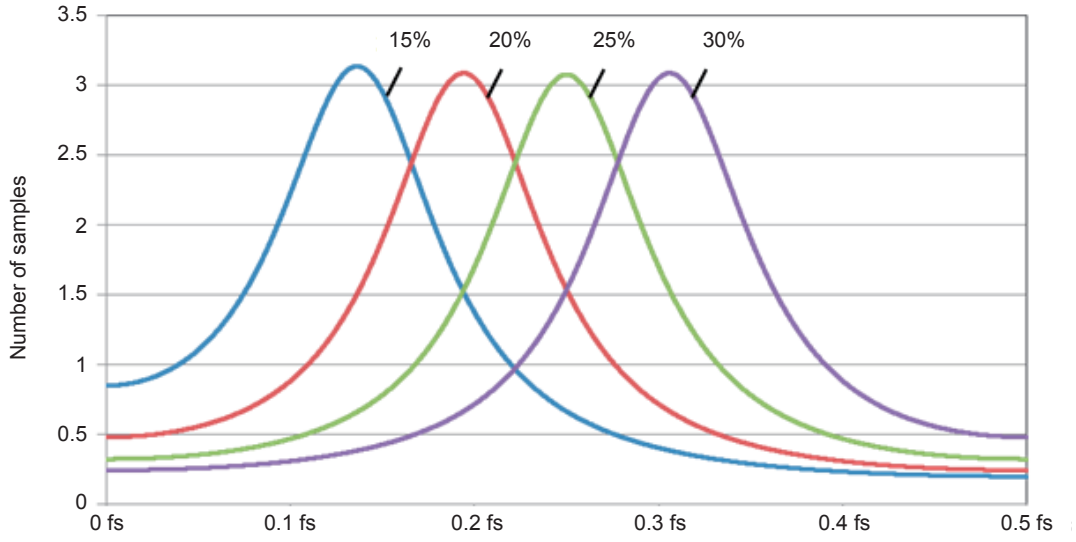


(fs: Calculation update rate [S/s])

Example of IIR–BPF (second order) frequency characteristics (bandwidth: 10%)

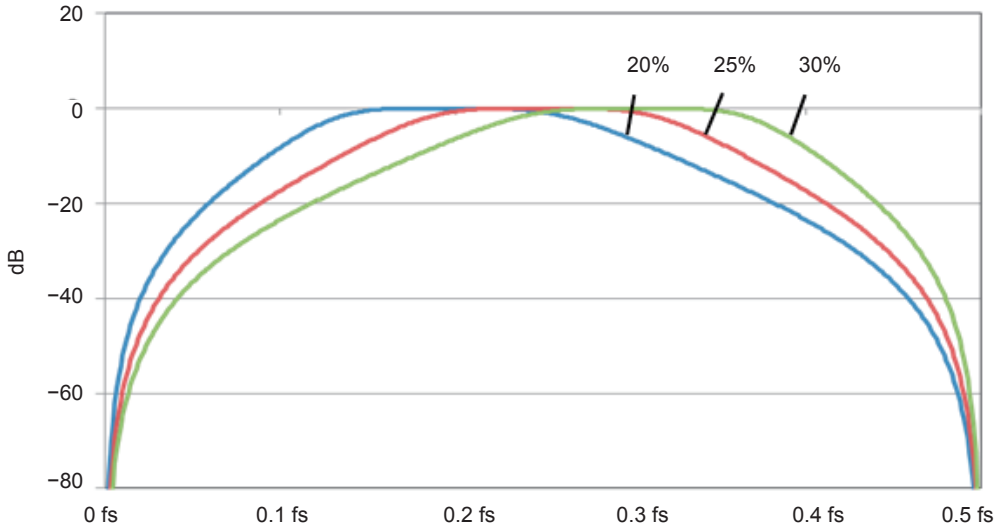


Example of IIR–BPF (second order) group delay characteristics (bandwidth: 10%)

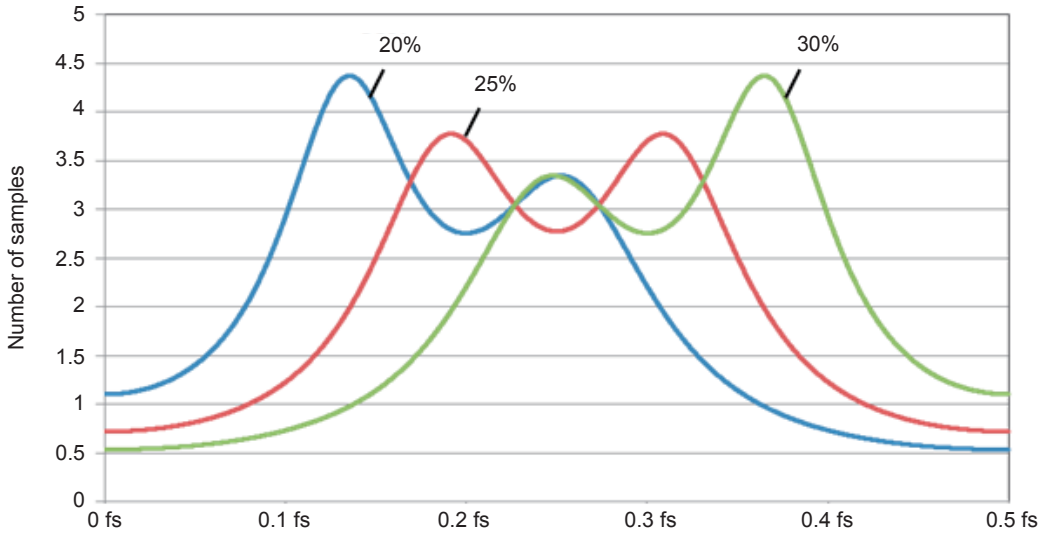


(fs: Calculation update rate [S/s])

Example of IIR–BPF (fourth order) frequency characteristics (bandwidth: 15%)

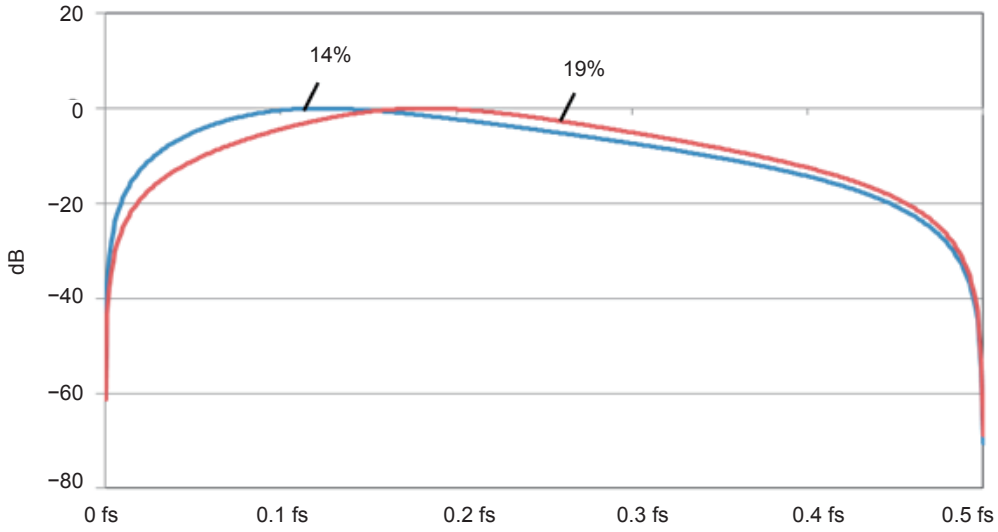


Example of IIR–BPF (fourth order) group delay characteristics (bandwidth: 15%)

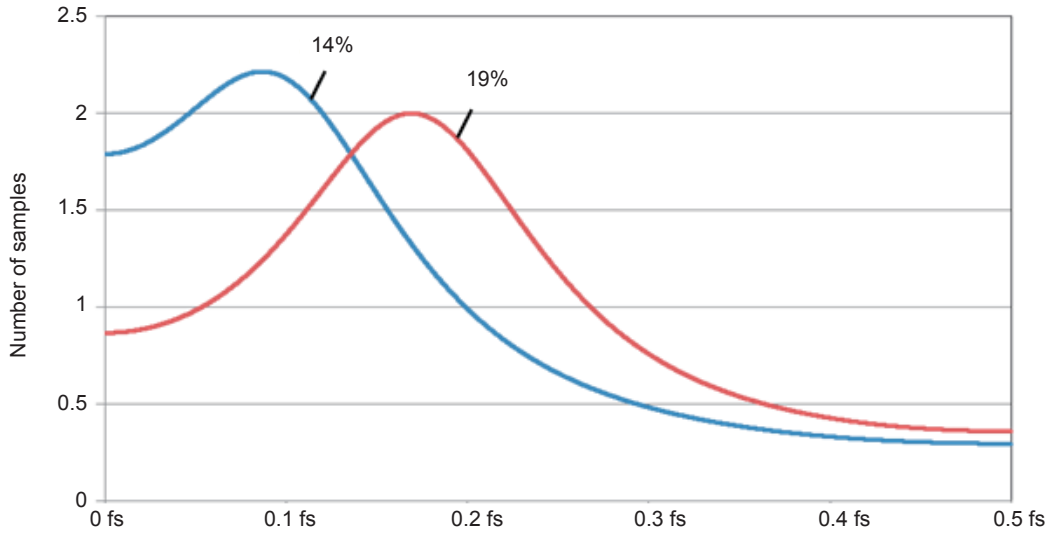


(fs: Calculation update rate [S/s])

Example of IIR–BPF (second order) frequency characteristics (bandwidth: 15%)

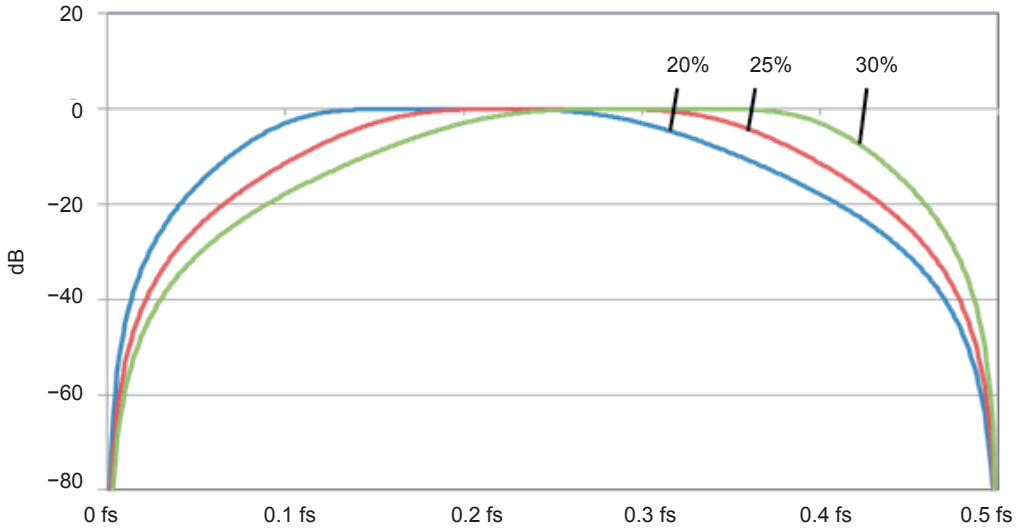


Example of IIR–BPF (second order) group delay characteristics (bandwidth: 15%)

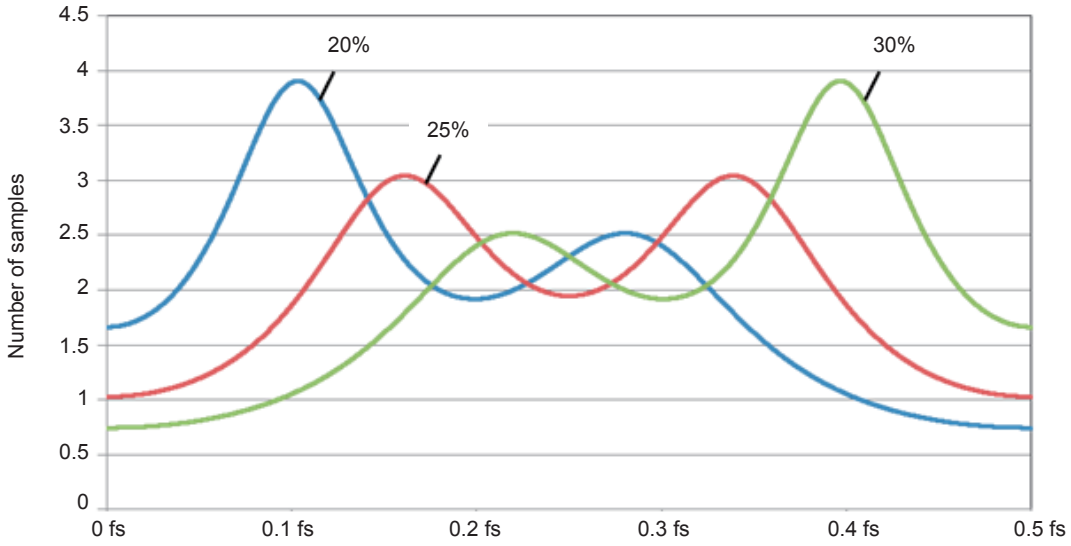


(fs: Calculation update rate [S/s])

Example of IIR–BPF (fourth order) frequency characteristics (bandwidth: 20%)

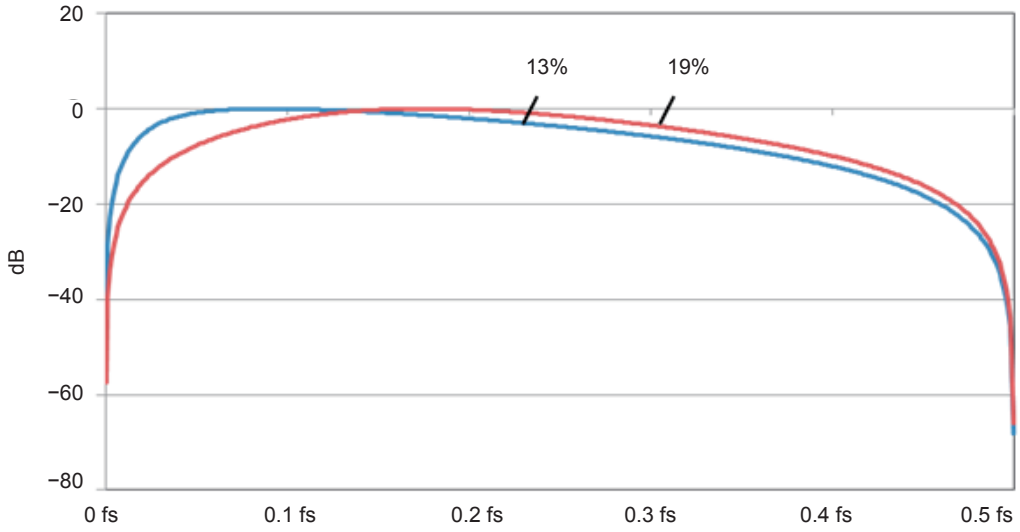


Example of IIR–BPF (fourth order) group delay characteristics (bandwidth: 20%)

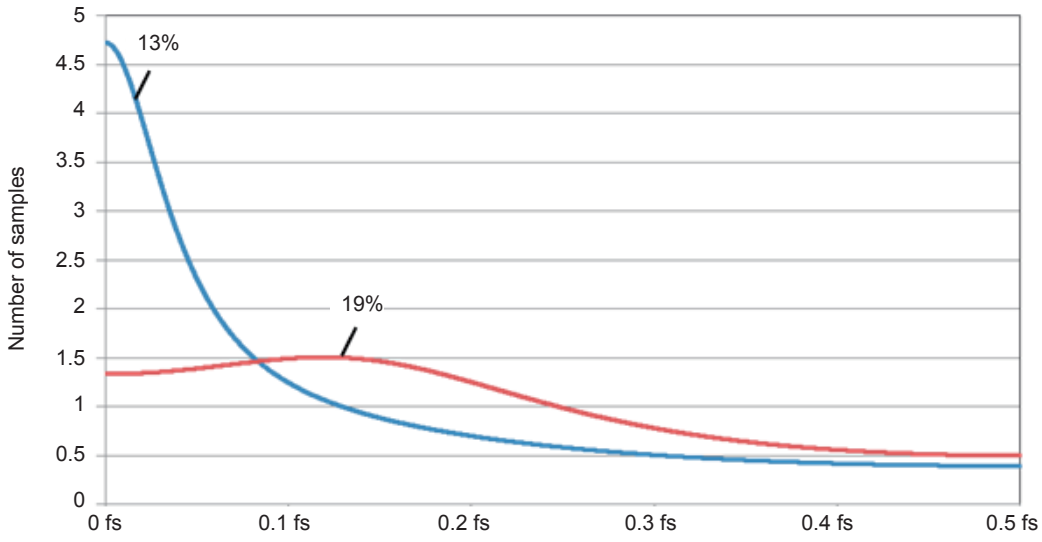


(fs: Calculation update rate [S/s])

Example of IIR–BPF (second order) frequency characteristics (bandwidth: 20%)



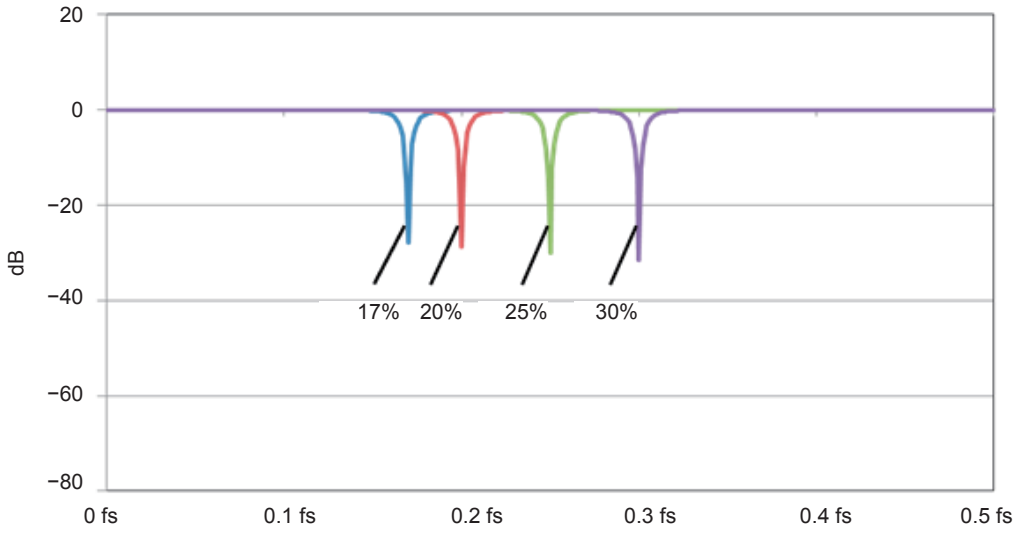
Example of IIR–BPF (second order) group delay characteristics (bandwidth: 20%)



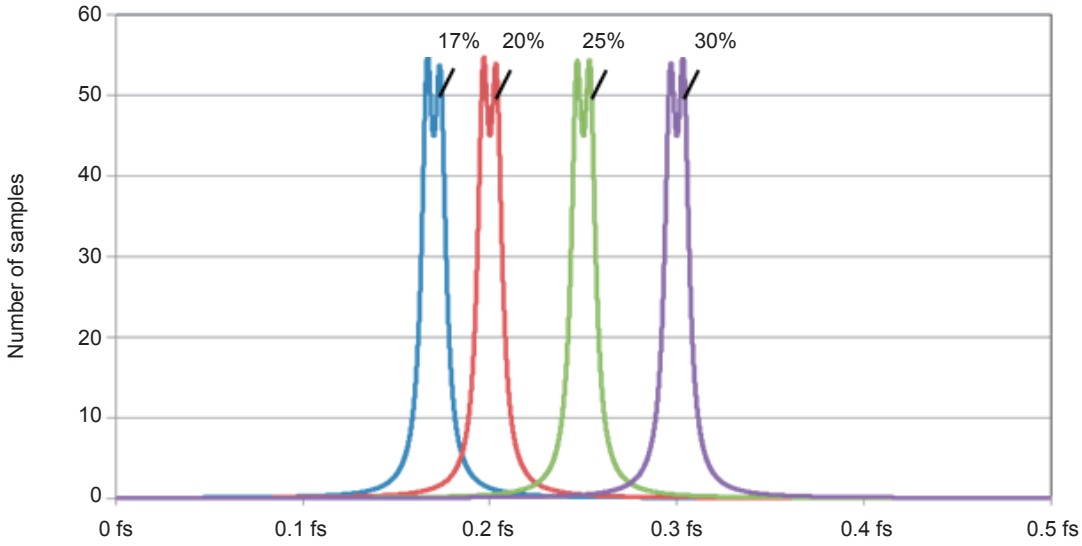
(fs: Calculation update rate [S/s])

Examples of BSF frequency characteristics diagram and group delay characteristics diagram

Example of IIR–BSF (second order) frequency characteristics (bandwidth: 1%)

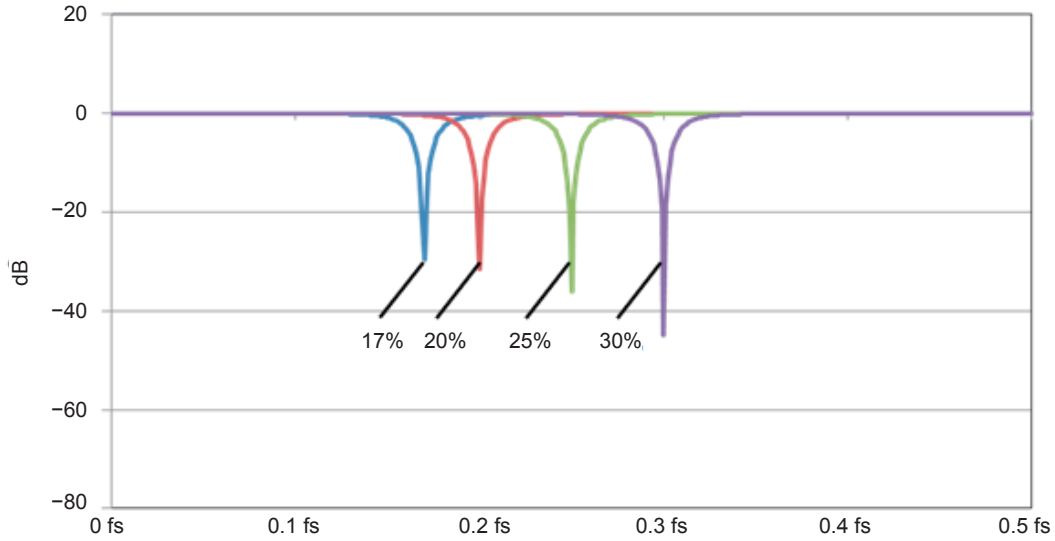


Example of IIR–BSF (second order) group delay characteristics (bandwidth: 1%)

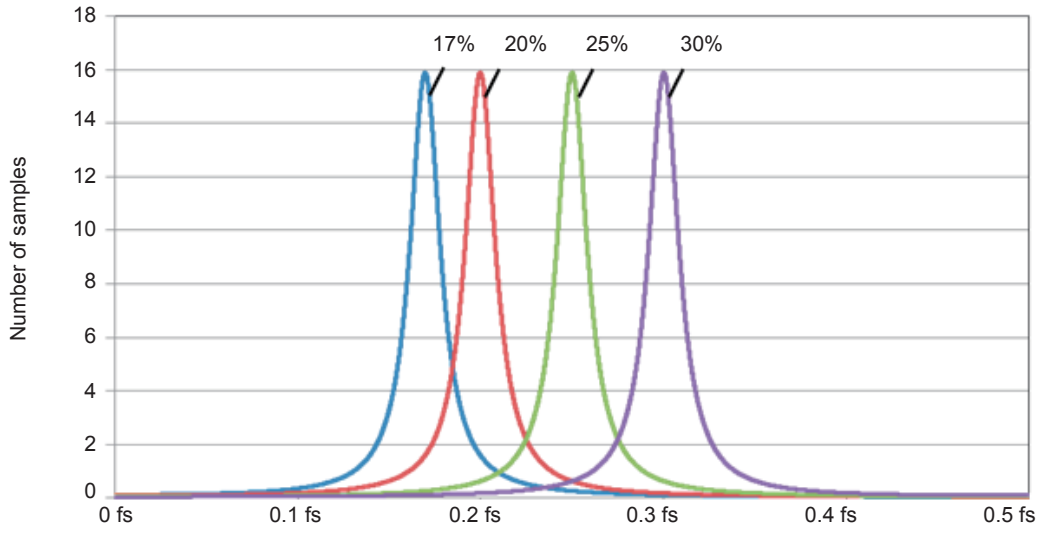


(fs: Calculation update rate [S/s])

Example of IIR–BSF (second order) frequency characteristics (bandwidth: 2%)

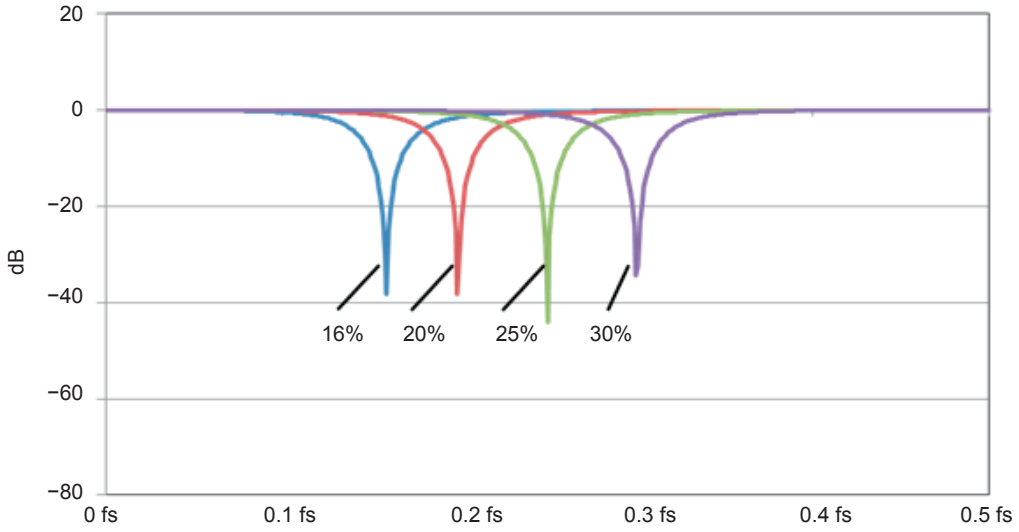


Example of IIR–BSF (second order) group delay characteristics (bandwidth: 2%)

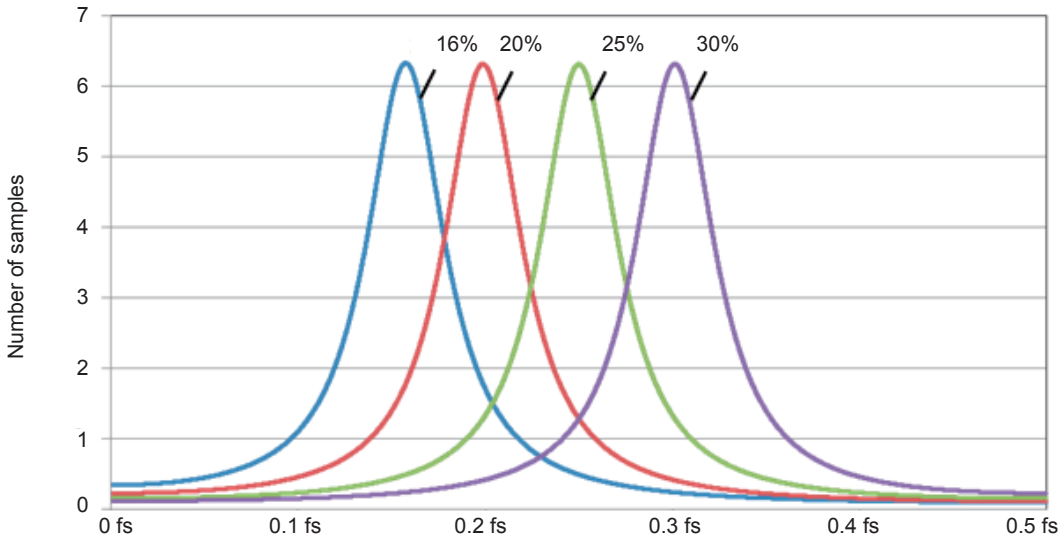


(fs: Calculation update rate [S/s])

Example of IIR–BSF (second order) group delay characteristics (bandwidth: 5%)

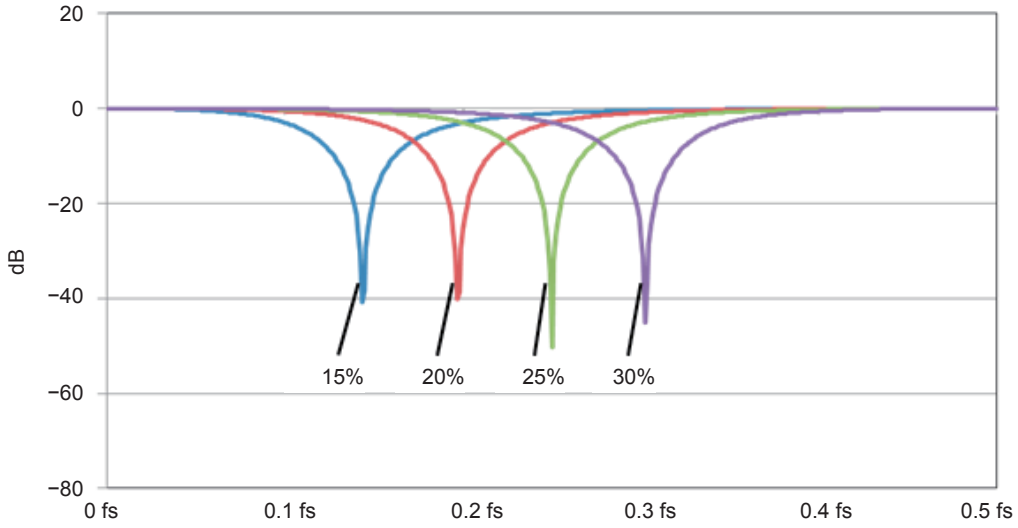


Example of IIR–BSF (second order) group delay characteristics (bandwidth: 5%)

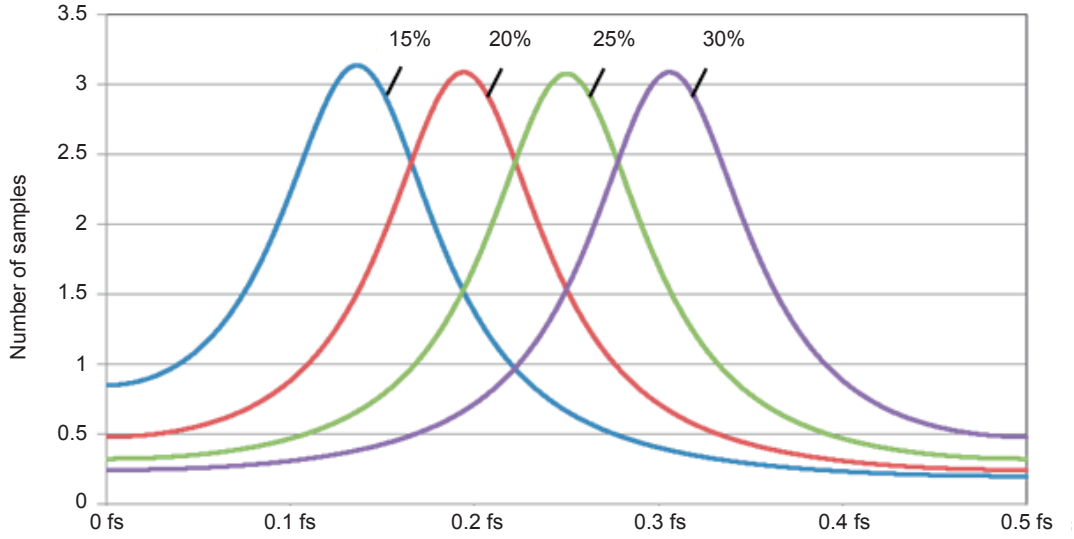


(fs: Calculation update rate [S/s])

Example of IIR–BSF (second order) frequency characteristics (bandwidth: 10%)

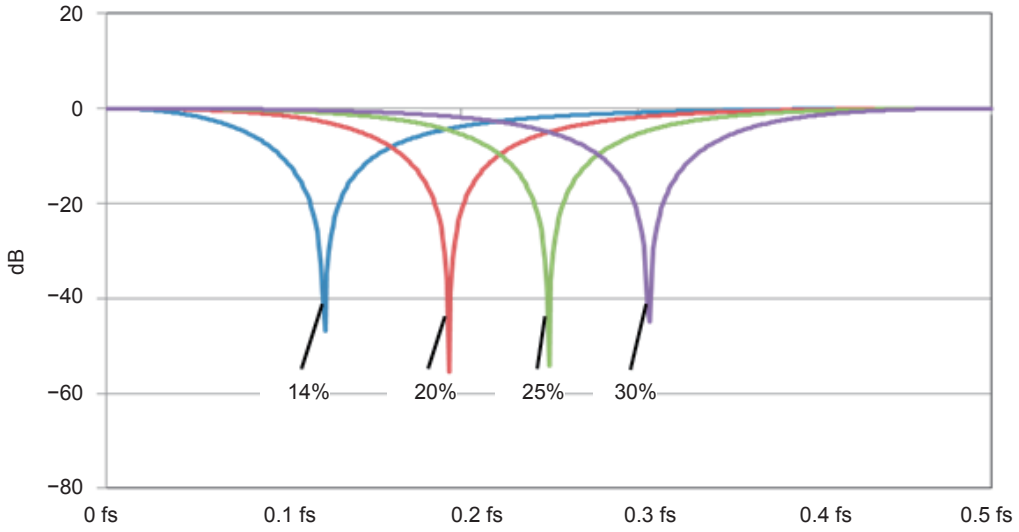


Example of IIR–BSF (second order) group delay characteristics (bandwidth: 10%)

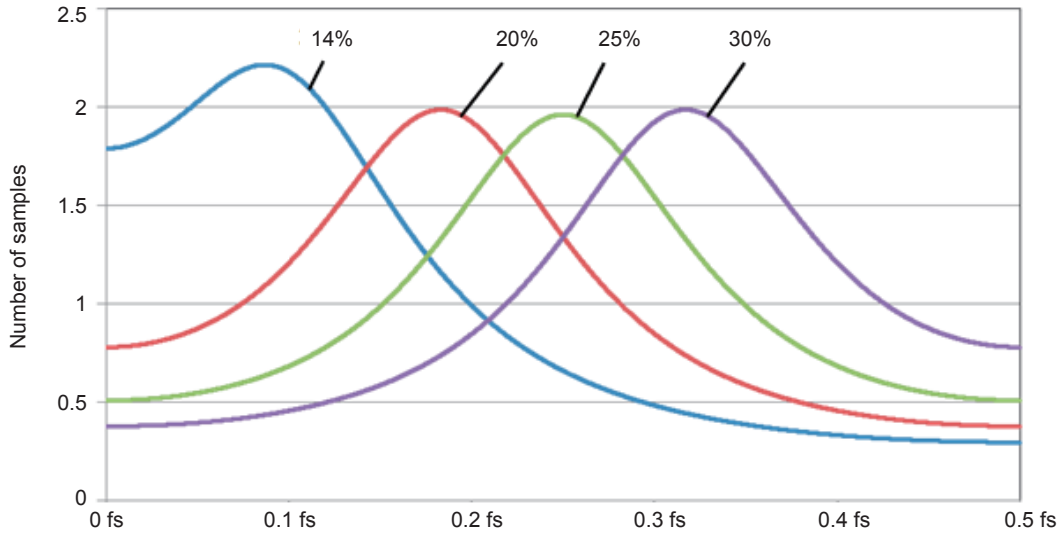


(fs: Calculation update rate [S/s])

Example of IIR–BSF (second order) frequency characteristics (bandwidth: 15%)

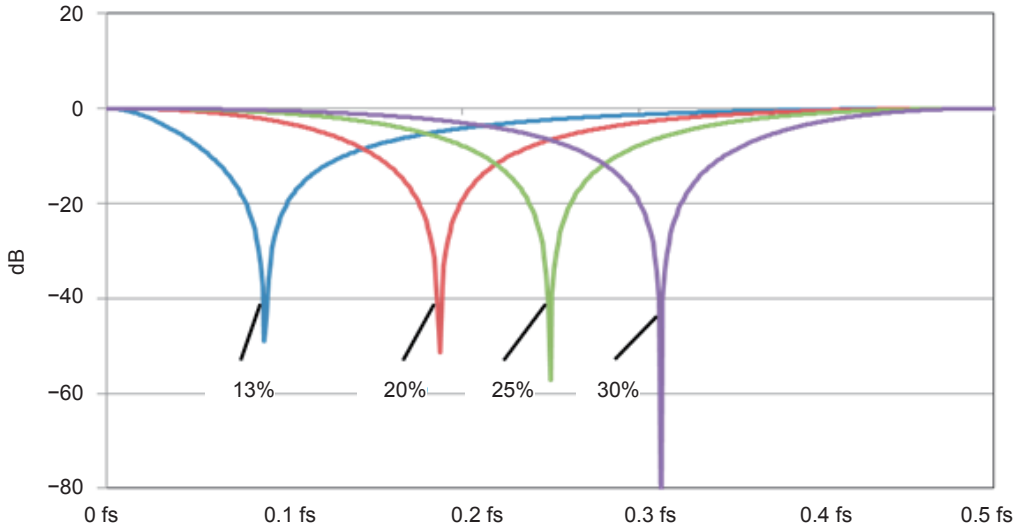


Example of IIR–BSF (second order) group delay characteristics (bandwidth: 15%)

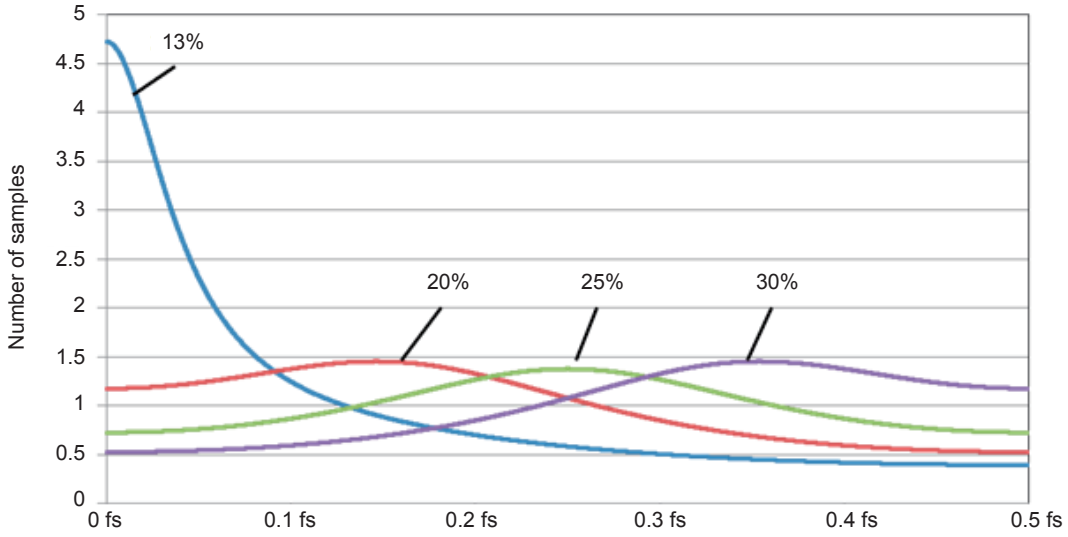


(fs: Calculation update rate [S/s])

Example of IIR–BSF (second order) frequency characteristics (bandwidth: 20%)



Example of IIR–BSF (second order) group delay characteristics (bandwidth: 20%)



(fs: Calculation update rate [S/s])

3.6 Moving Average Filter Characteristics

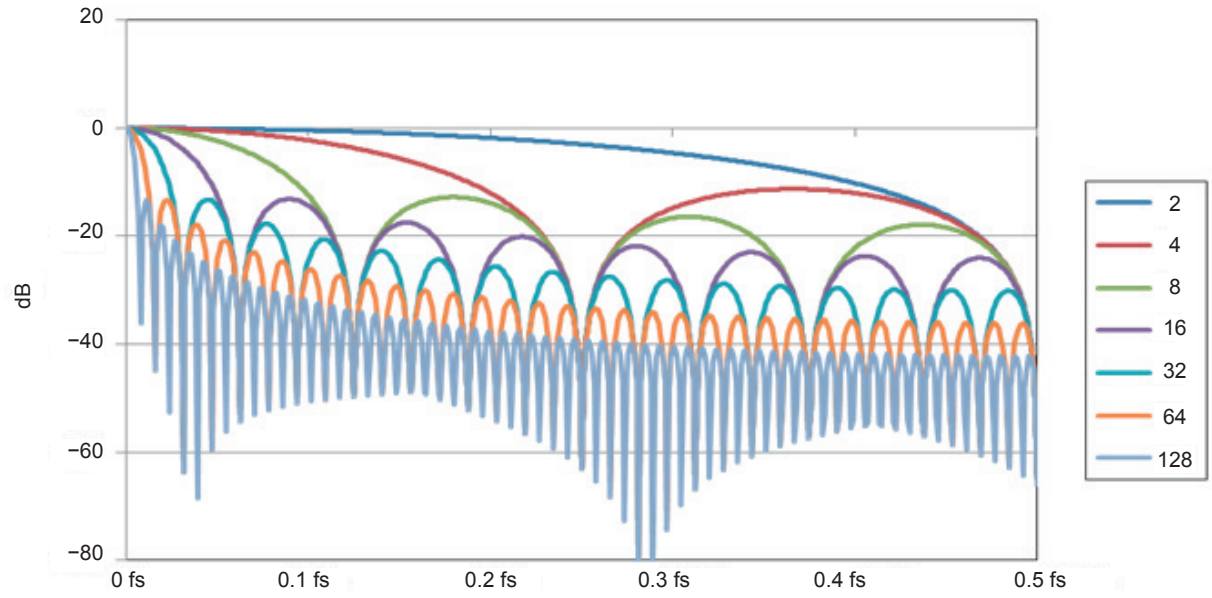
The moving average filter is one of the low-pass filters.

Group delay time

Group delay time = (Number of taps− 1) T / 2
Where the T is the calculation update interval.

Example of frequency characteristics diagram

Example of moving average frequency characteristics



(fs: Calculation update rate [S/s])

3.7 Differential Calculation Characteristics

Fifth order Lagrange interpolation formula is used for differential calculations of the real-time waveform calculation.
Refer to “Calculation type” (p. 24).

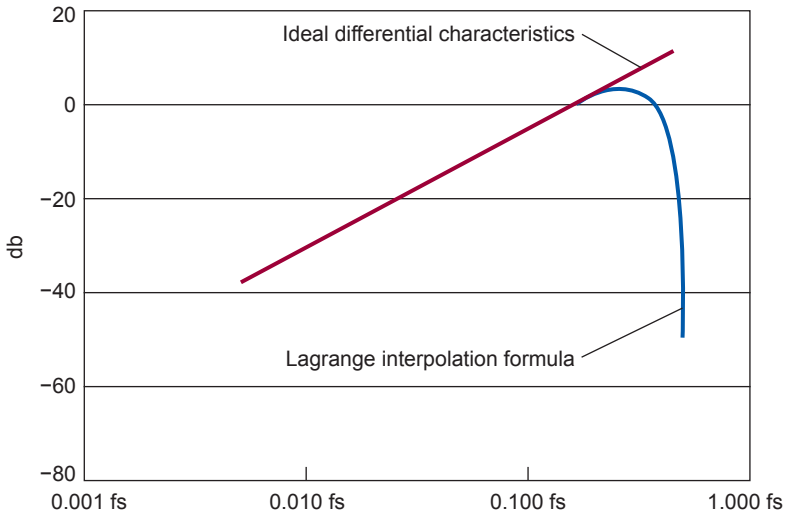
Response time

Response time = 2* × Calculation update interval × Differential interval

*: Delay based on the fifth-order Lagrange interpolation formula

Example of frequency characteristics diagram

Frequency characteristics diagram for differentiation



(fs: Calculation update rate [S/s])

When an input frequency is within 20% of the calculation period, the differential characteristics is nearly equal to ideal differential characteristics. Frequency components higher than the above are suppressed due to the high range characteristics of Lagrange interpolation formula.

HIOKI

http://www.hioki.com

Our regional contact information

HEADQUARTERS
81 Koizumi
Ueda, Nagano 386-1192 Japan

HIOKI EUROPE GmbH
Rudolf-Diesel-Strasse 5
65760 Eschborn, Germany
hioki@hioki.eu

1808EN

Edited and published by HIOKI E.E. CORPORATION Printed in Japan